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OPERATIONS AND MAINTENANCE WORKSHOP

COURSE MANUAL

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OPERATIONAL MONITORING AND MAINTENANCE

PHASE 1 - SOLAR ASSISTED DOMESTIC HOT WATER PACKAGED SYSTEMS

CLOSED LOOP SYSTEMS

REVISED MARCH 1984

OPERATIONAL MONITORING AND MAINTENANCE

PHASE 1 SOLAR ASSISTED DOMESTIC HOT WATER PACKAGED SYSTEMS

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INTRODUCTION

The general concept of Operational Monitoring and Maintenance is to provide methods of ensuring:

- that the solar heating system is operating as designed.
- that operational problems and system breakdowns are detected as early as possible.
- that action is taken before serious damage and expensive repairs are incurred.
- that a long life expectancy of the system can be realized.
- that long-term operation and maintenance costs are kept to a minimum.
- that maintenance is performed on a regular, scheduled basis.

MONITORING STRATEGY

The methodology by which monitoring is accomplished for the packaged solar heating systems should take into account:

- that instrumentation essentially be kept basic and inexpensive,
- that routine inspection and simple diagnosis can be performed by non-technical individuals such as building maintenance staff,
- that operational check lists and maintenance schedules become part of a regular maintenance program,
- that simple corrective measures or other actions can be administered by non-technical individuals such as building maintenance staff,
- that simple records can be kept on a regular basis, useful for further examination and diagnosis by a technician, and
- that provisions are made in the system to facilitate the connection of precision instruments required for commissioning, fine tuning, trouble shooting, and performance verification by the technical staff.

OPERATIONAL MONITORING AND MAINTENANCE

PHASE 1 - SOLAR ASSISTED DOMESTIC HOT WATER PACKAGED SYSTEMS

CLOSED LOOP SYSTEM

Types of Systems

Three different categories of solar-assisted domestic hot water packaged systems are described in publications issued by the Canadian Solar Industries Association, as follows:

(A) Closed Loop Systems
(B) Drain-back and Pressurized Drain-back Systems

This volume deals only with (A) Closed Loop Systems

The following systems fall into this category:

Nortec/Norsun Solar Industries Incorporated
(Solar Product Data Sheet 17)

Tempspec Specialties Mfg. Ltd.
(Solar Product Data Sheet 18)

Sun-Ray Solar Systems Limited
(Solar Product Data Sheet 20)

Petro-Sun Incorporated
(Solar Product Data Sheet 22)

Sol-Can Limited
(Solar Product Data Sheet 23)

Solatherm Incorporated
(Solar Product Data Sheet 27)

Amherst Renewable Energy Limited
(Solar Product Data Sheet 28)

Thermo Dynamics Models TDA150, 225 and 300

(A) Closed Loop System - cont'd

1. General Description of Systems

Except for minor variations, the design of these systems is similar in basic concept and operation. They are primary-secondary heating systems.

The primary circuit consists of a pressurized loop containing as the heat transfer liquid an anti-freeze solution which is circulated through the solar collectors and the heat exchanger. The heat transfer liquid contained in the primary circuit is circulated by a pump whenever heat is available at a temperature suitable to provide domestic water heating. The secondary circuit consists of the domestic water contained in, and flowing through, the storage tank and/or heat exchanger.

Certain systems differ from the others in that the heat exchange is achieved through a counterflow, double tube bundle, with forced circulation for both the primary and secondary circuits. A variety of double wall heat exchangers is now available for added protection against cross contamination between glycol and domestic water circuits.

All of the systems are controlled by an ON-OFF temperature differential controller with sensors located at or near the outlet of the collector and at or in the domestic water tank. The pump(s) are activated upon a temperature differential, adjustable between 8°C and 11°C Δ T and are de-activated upon a temperature differential, adjustable between 1.5°C and 3°C Δ T.

(A) Closed Loop System - cont'd

Although all systems are similar in basic concept and operation there are differences in the application and placement of components forming part of the hydronic circuit, such as the location of the expansion tank relative to the pump, the location and setting of the pressure relief valve, and the locations of the heat exchanger and check valve.

The relationship between the location of the expansion tank and the pump has an effect upon the minimum safe system pressure (fill pressure) of the closed loop as well as on the acceptance volume of the expansion tank. Systems with expansion tanks located at the discharge of the pump require a higher fill pressure than systems with expansion tanks located on the suction side of the pump. In order to minimize the risk of cross-contamination between the anti-freeze (propylene-glycol/water mixture) and the potable water, it is desirable to maintain the system pressure in the primary loop as low as possible and below that in the secondary loop. Since city water pressure usually fluctuates between 40-70 psig(275-485 kPa), the pressure in the closed loop should be kept below this level.

Note: Some of the earlier literature on certain package systems indicated the connection of the expansion tank to the discharge side of the circulating pump. In this type of arrangement the pump head acts on the system as a negative component and thus requires a correspondingly higher system fill pressure.

It is recommended that expansion tanks for all package systems be placed on the suction side of the pump to facilitate the lowest possible operating pressures within the closed loop.

(A) Closed Loop System - cont'd

The safe minimum system pressure (fill pressure) is established by the Contractor during commissioning when the closed loop is charged with the anti-freeze solution. Generally, at that time, the temperature of the fluid is between 4°C and 30°C.

Since all of the packaged systems are equipped with the same diaphragm type expansion tank (EXTROL S-15), the final pressure, which will be reached when the solar loop is at maximum temperature (eg: 90°C), will depend upon the volume of anti-freeze contained in the primary loop and the fill pressure originally set up for the particular installation.

The following graphs display the temperature/pressure relationships for typical closed-loop systems, categorized for one, two and three-storey buildings.

It can be seen that systems for single-storey residences which have very direct pipe runs between the heat exchanger and collectors and correspondingly low anti-freeze volumes will show considerably lower final system pressures compared with systems for multi-storey buildings with lengthy pipe runs.

Note:
The minimum fill pressure is established by adding a safe margin of pressurization to the system static head. In the tables following, a pressurization component of 35 kPa (5 psig) was used. This should be considered as a minimum level and, where permitted by system volume and static head as determined from the following charts, the minimum fill pressure should be increased by 30 to 50 kPa. The charts also show the correspondence of the relief valve setting with the pressure response of the particular systems.

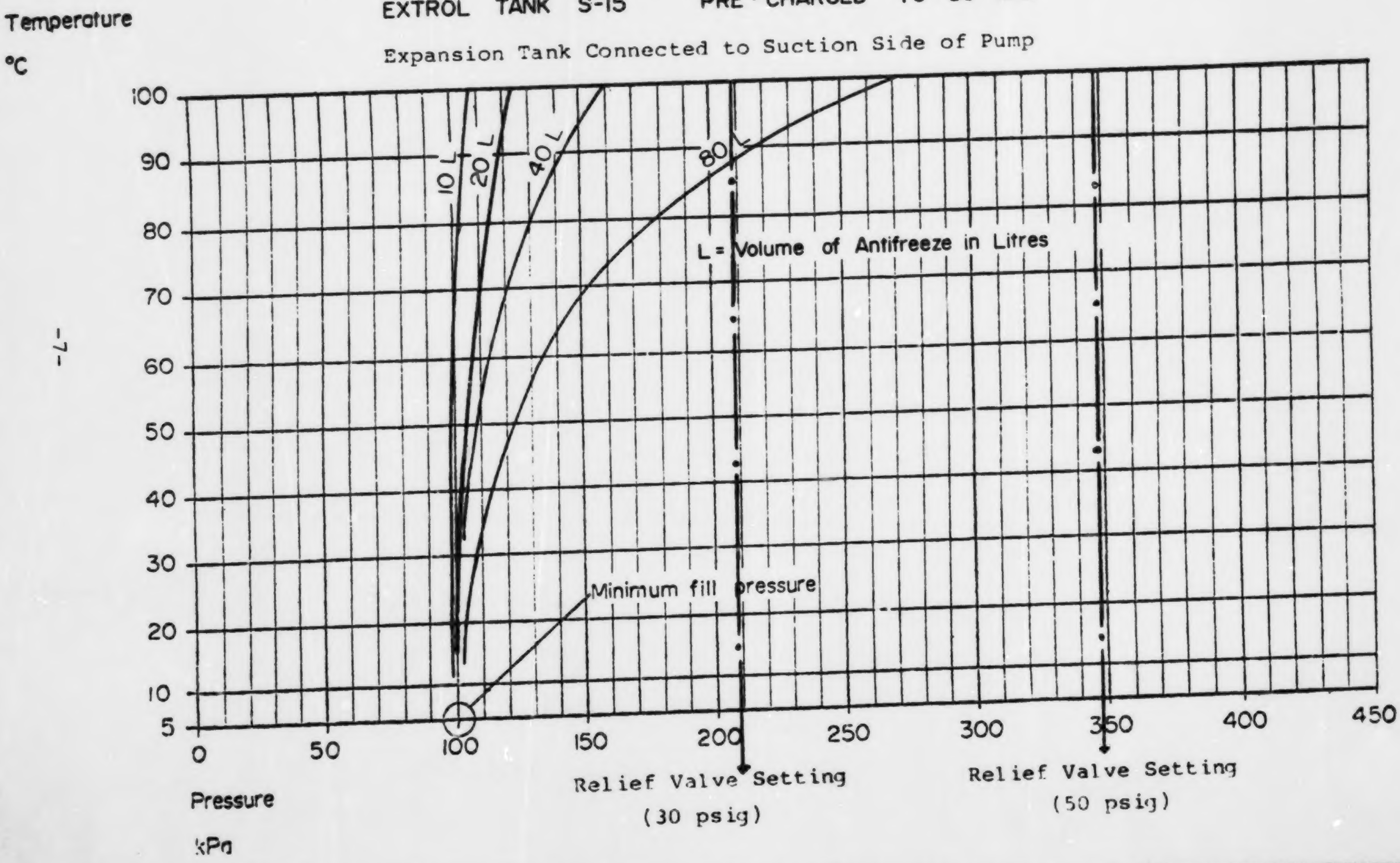
Temperature - Pressure Relationship. CLOSED LOOP

SINGLE STOREY BUILDING

Max. 6.7 m measured between exp. tank and top of collector

EXTROL TANK S-15 PRE - CHARGED TO 85 kPa

Expansion Tank Connected to Suction Side of Pump



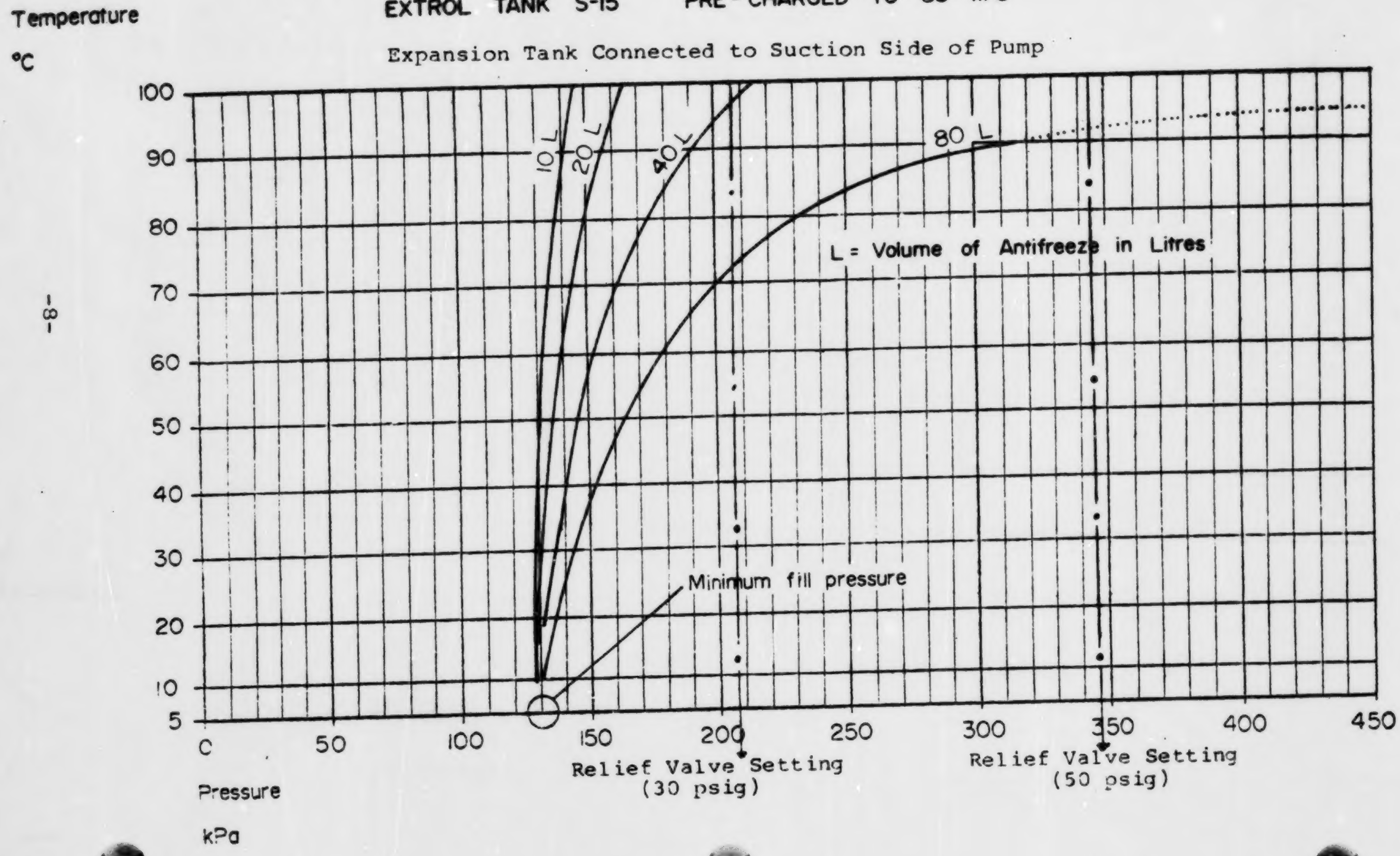
Temperature - Pressure Relationship. CLOSED LOOP

TWO STOREY BUILDING

Max. 10 m measured between exp. tank and top of collector

EXTROL TANK S-15 PRE - CHARGED TO 85 kPa

Expansion Tank Connected to Suction Side of Pump



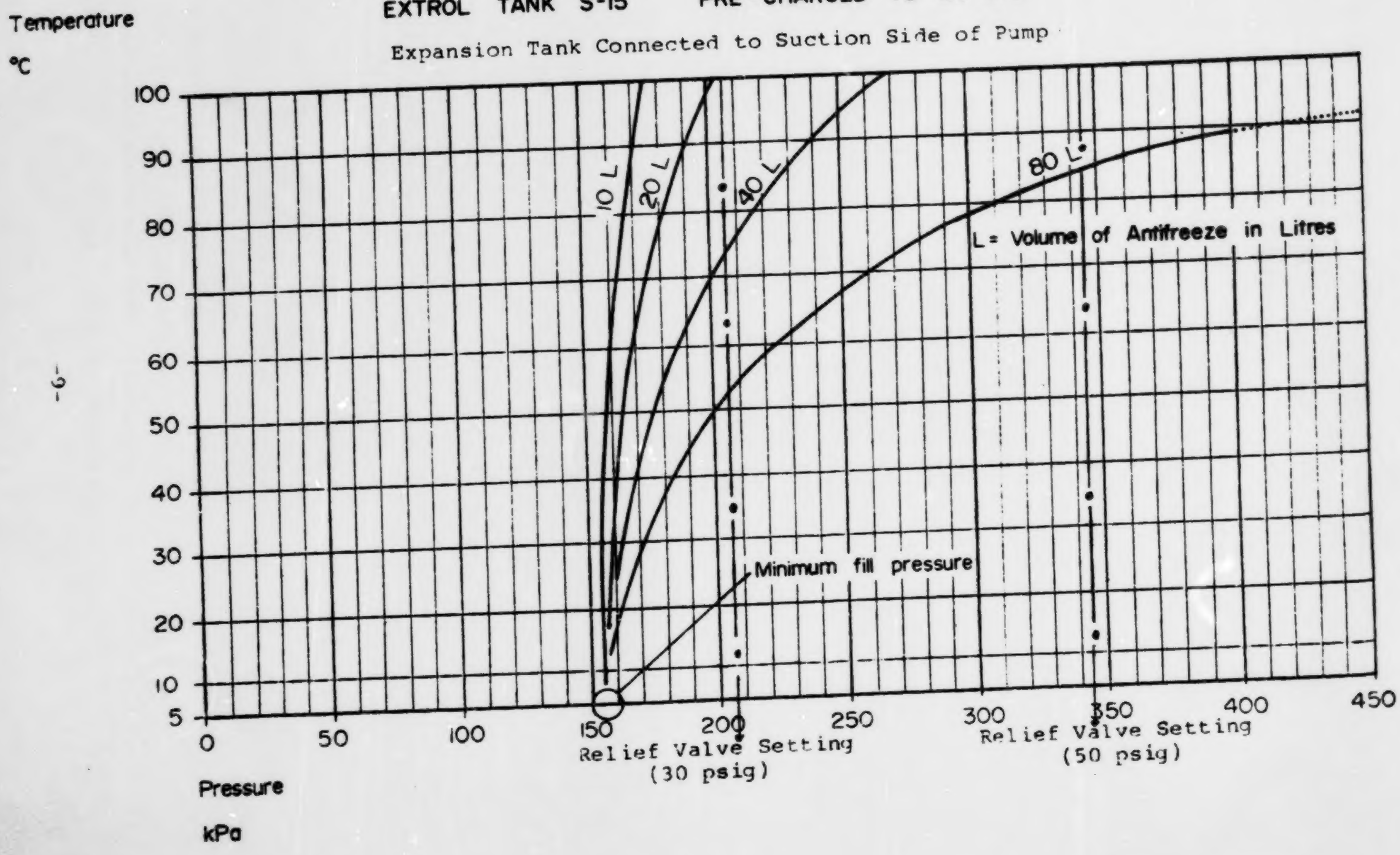
Temperature - Pressure Relationship. CLOSED LOOP

THREE STOREY BUILDING

Max. 12.8 m measured between exp. tank and top of collector

EXTROL TANK S-15 PRE-CHARGED TO 85 kPa

Expansion Tank Connected to Suction Side of Pump



(A) Closed Loop System - cont'd

2. System Components

(a) Collectors

The solar collectors (dealt with in this manual and provided with all solar domestic hot water packages for closed loop systems) are of a "flat plate" configuration. Heat is absorbed by a blackened surface to which a fluid circuit in the form of copper header or serpentine loop is firmly attached. The black surface, called the absorber, gains heat when subjected to sunlight; the fluid, when circulating through the passages, heats up and transmits the solar energy (heat) to the domestic water through the closed loop (primary) circuit and heat exchanger.

- The back and sides of the absorber are insulated and the cover is usually a heat tempered, low iron, single pane glass. The space between absorber and glass cover is vented to the atmosphere through several vent holes.
- Collectors are joined in series by copper couplings or by a high temperature silicone hose connection with stainless steel clamps, depending upon the manufacturer's recommenations.
- Panel mounting and collector feed and return connections must be installed to permit movement sufficient to accommodate any expansion and contraction of the total roof-mounted system.
- All copper joints between collectors and in piping within at least 3 meters of the collectors, must be made with 95-5 or silver solder (including repairs), because of the high absorber temperatures involved during stagnating conditions and the pipe stresses incurred due to expansion and contraction.

(A) Closed Loop System - cont'd

2. Components - cont'd

(a) Collectors - cont'd

- Where collector tilt is 60° and higher, snow accummulation and build-up does not usually last long enough to be of any concern. On systems with lower tilt angles, however, the removal of snow from collector surfaces may become necessary in certain regions.
- Condensation behind the glass cover may become visible during certain outdoor temperature conditions but should soon disappear after the collectors have been exposed to direct sunshine. If condensation remains during sunny periods, check vent openings and ensure that the collectors are properly ventilated. Where collectors are completely flashed into the roof, special provisions must be made to ensure proper venting.
- Surface contamination of the absorber can be a problem in dusty, dry areas since a thin layer of dust can affect adversely the system performance. Dismantling of the collector cover and cleaning of the absorber surface may be necessary several times during the active life of the system.
- Cleaning of collector covers may be necessary depending upon the local ambient environment; in many installations the natural washdown during rains will keep the collectors reasonably clean.

(A) Closed Loop System - cont'd

2. Components - cont'd

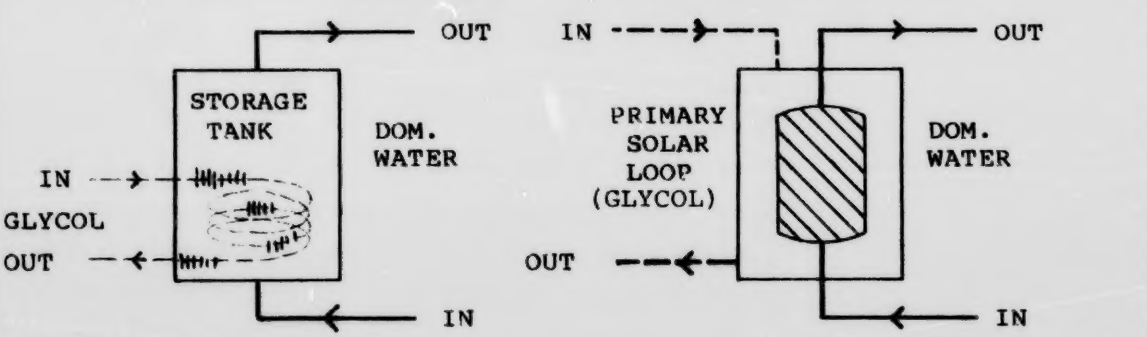
(a) Collectors - cont'd

Pipe insulation on collector feed and return lines exposed to the outdoors must have a watertight jacket. A type of insulation which is inherently non-water absorbent has proven to be most suitable for this application.

(b) Heat Exchangers

A variety of heat exchangers is now available from solar system manufacturers.

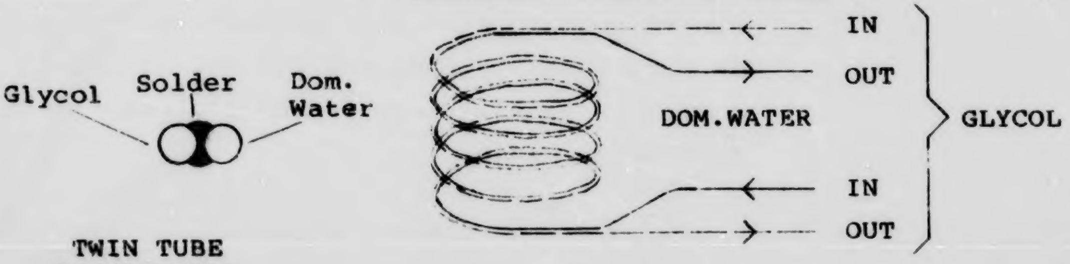
Single Wall Heat Exchanger



INTERNAL SINGLE WALL
FIN AND TUBE
HEAT EXCHANGER

DOUBLE MANTLE
HEAT EXCHANGER

Double Wall Heat Exchanger

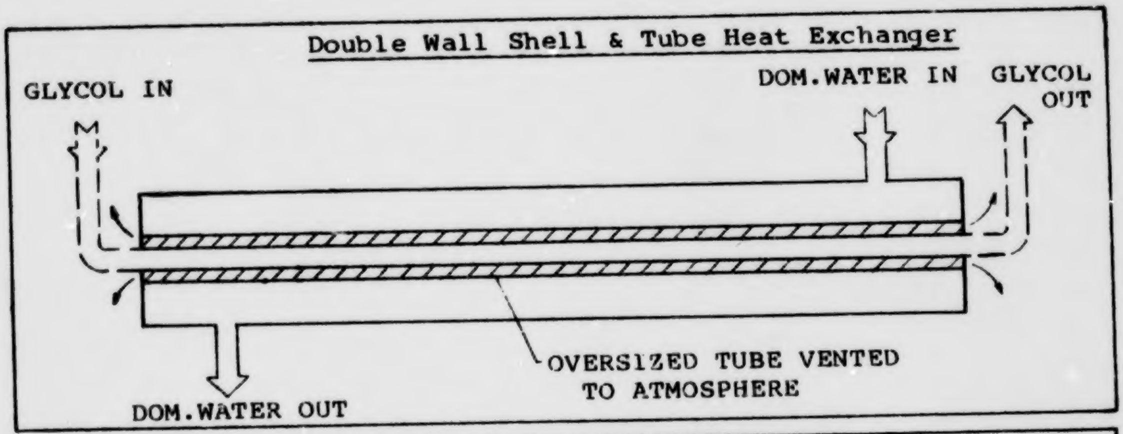


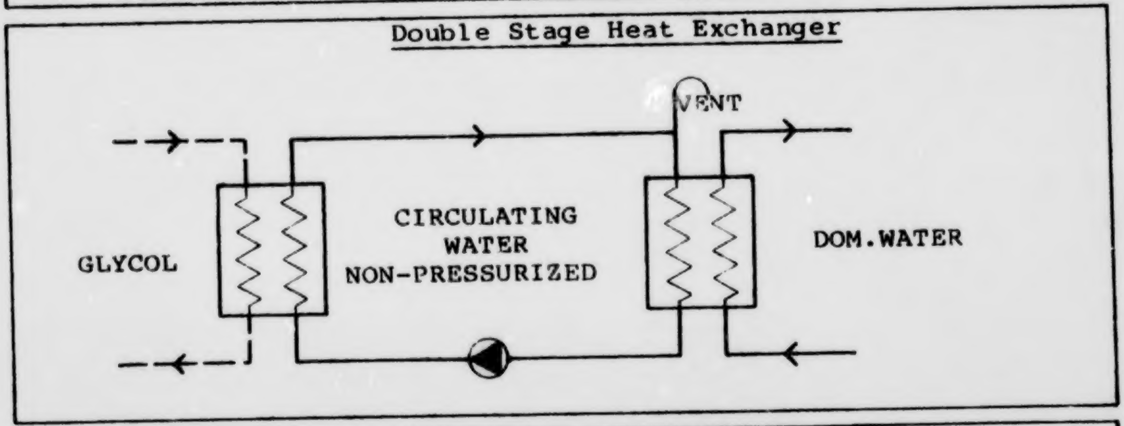
TWIN TUBE
DOUBLE WALL
HEAT EXCHANGER

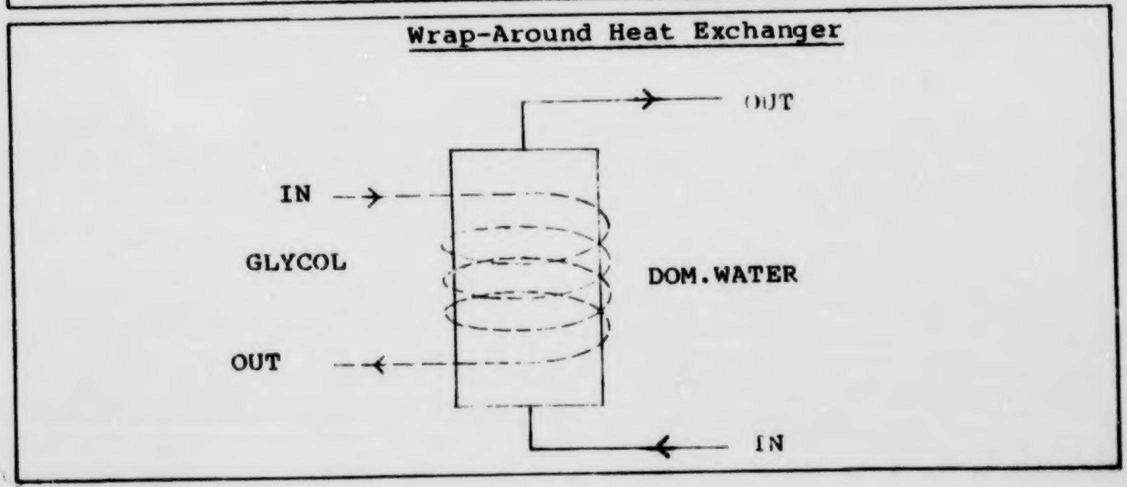
(A) Closed Loop System - cont'd

2. Components - cont'd

(b) Heat Exchangers - cont'd


Double Wall Shell & Tube Heat Exchanger


Double Stage Heat Exchanger


Wrap-Around Heat Exchanger

(A) Closed Loop System - cont'd

2. Components - cont'd

(b) Heat Exchangers - cont'd

In many areas local plumbing codes will not permit the use of single wall heat exchangers even though propylene-glycol is used as the antifreeze. Although propylene-glycol is considered relatively non-toxic if consumed in small quantities, the additives (such as the corrosion inhibitor and the anti-foaming agent) are not 'food' grade. In some areas local plumbing codes will permit the use of ethylene glycol in conjunction with double wall type heat exchangers. This would be advantageous in several ways: ethylene glycol is readily available, is less costly, and offers a more efficient heat transfer.

(c) Circulating Pumps

The circulating pump in the closed loop can be of "standard" construction and, where a pump is used in the domestic water circuit, it must be "bronze fitted".

If there is no air present in the system the pump runs very quietly.

(A) Closed Loop System - cont'd

2. Components - cont'd

(c) Circulating Pumps - cont'd

Pumps installed horizontally may, initially, require some time to purge the volute free of air. Closed loop fluid balancing should be performed only after the system is completely air-vented; even a small amount of air will noticeably affect pump performance.

(d) Expansion Tank

Most systems are provided with a diaphragm type expansion tank EXTROL Model S-15. This tank has an acceptance volume of 3.0 liters (not 3.8 liters as stated by most solar system manufacturers) and is usually pre-charged with air to 85 kPa. Before filling the system with anti-freeze the air pressure of the expansion tank must be checked with a pressure gauge and, if necessary, recharged to 85 kPa (12 psig).

After the system is filled with glycol the air pressure in the expansion tank will automatically assume a pressure equal to that measured in the closed circuit loop at the same elevation. Any verification of correct expansion tank pre-charge pressure, therefore, is valid only with a drained down system. The expansion tank diaphragm must be of EPDM construction, a material which is compatible with propylene glycol.

(A) Closed Loop System - cont'd

2. Components - cont'd

(d) Expansion Tank - cont'd

The maximum operating pressure rating of the EXTROL Model S-15 is 520 kPa (75 psig); it usually represents the component in the system with the lowest operating pressure rating. For this reason the maximum relief valve setting must be 520 kPa (75 psig).

In some provinces, codes do not permit the S-15 expansion tank to be used in systems with operating pressures above 210 kPa (30 psig); such systems require ASME rated tanks constructed as pressure vessels.

(e) Relief Valves

The closed loop system and its components are protected from excessive pressure build-up by the relief valve. There are several factors which may determine the correct choice or setting of the relief valve:

1. The maximum setting of the relief valve must not exceed the maximum operating pressure rating of any component in the system (ie: the EXTROL S-15 expansion tank normally supplied with solar system packages is designed for a maximum operating pressure of 520 kPa (75 psig).

(A) Closed Loop System - cont'd

2. Components - cont'd

(e) Relief Valves - cont'd

2. In certain provinces the EXTROL S-15 tank may be used only up to 210 kPa (30 psig). Systems which exceed 210 kPa (30 psig) must have ASME rated expansion tanks. Subsequently,the relief valve setting for Extrol S-15 applications must be limited to 210 kPa in these regions.

3. In order to protect the domestic water circuit from cross-contamination it is desirable (where single wall heat exchangers are used) to maintain the lowest possible pressure in the glycol circuit. With the knowledge of system height and quantity of fluid, the lowest practical setting of the relief valve could be established by referring to the curves entitled "Pressure-Temperature Relationship".

Important Note

All parts of systems must be protected from the possibility of excessive pressure build-up. Where the collector loop has shut-off or balancing valves installed on the collector feed and on the return line, thereby allowing total isolation of the heat source (collector), an additional relief valve must be installed within this isolated part of the collector circuit.

(A) Closed Loop System - cont'd

2. Components - cont'd

(f) Check Valve

The check valve in the primary circuit performs an important function. It prevents gravity reverse flow (which otherwise would occur during periods when the pump is off and while stored liquid is at a temperature higher than the outdoor temperature) which would result in wasted energy. The check valve may be located almost anywhere within the loop; a vertical up-flow position is preferred. NOTE: If the check valve is installed on the collector feed, the balancing valve must also be located on the collector feed line.

(g) Air Vent

The automatic float vent installed at the top of the primary loop must always be installed complete with shut-off valve. After all air is bled from the loop (following commissioning and start-up) the air vent must be isolated from the circuit. An active automatic float vent could vent anti-freeze vapour to atmosphere in a collector stagnating condition; under other circumstances it could act as a vacuum breaker.

For best results, once the system has been commissioned, the automatic air vent at the top of the loop should, therefore, be isolated or removed.

(A) Closed Loop System - cont'd

2. Components - cont'd

(g) Air Vent - cont'd

Some system packages include additional automatic air vents and air purgers, installed directly ahead of the circulating pump. An automatic air vent at this location could remain active and should not be isolated.

(h) System Balancing Valve

The system balancing valve normally is a single lever ball type device. It must be located in the collector feed line if the check valve is located in the feed line and may be located in the collector feed or return line if the check valve is located in the return line. This rule must be strictly observed to prevent the possibility of isolating the collectors from the relief valve and the subsequent, uncontrolled buildup of pressure.

(i) Controller

The controllers for solar domestic hot water systems, while varying somewhat from one manufacturer to another, are all designed to operate in the same manner. As long as there is enough solar or thermal energy arriving at the collectors to heat the system fluid to a temperature above that currently in the solar storage tank, the controller is set to turn on the circulating pump(s) and make the solar heat collection/transfer system active.

(A) Closed Loop System - cont'd

2. Components - cont'd

(i) Controller - cont'd

Most controllers operate by means of a differential temperature measurement; the temperature at a remote sensor on or near the collector panel outlet is continuously compared with a temperature at or near the storage tank domestic cold water inlet. If the temperature difference is sufficient, the system is switched to the "on" state. The "turn-on" differential for closed loop systems is generally between 8-11°C and the "turn-off" differential is generally between 1-3°C. On certain controllers these setpoints are adjustable and may be calibrated; on others the setpoints are factory sealed.

Rapid cycling of a controller usually indicates that the on-off differential is set too close or that the water flow is too high , whereas too infrequent cycling indicates that the differential may be set too wide or that the water flow is restricted.

Certain controllers incorporate other standard features within the basic unit. Examples of such features include high and low temperature alarms and system lockouts (good features if they are activated by separate sensors), and additional sensor pairs which measure and control from collector inlet-outlet temperatures of the liquid.

(A) Closed Loop System - cont'd

2. Components - cont'd

(i) Controller - cont'd

After an initial turn-on and delay time activated by the collector/storage tank sensor pair, the controller is set to maintain the solar collection system in the "on" state as long as the temperature of water leaving the collectors is significantly higher than that entering.

At present most controllers use thermistor sensors which decrease their resistance with increasing temperature, while some others use integrated-circuit or RTD sensors (see Temperature Sensors, Large System Manuals).

Caution should be observed when installing, calibrating and repairing differential controllers to ensure that specified, exact replacement sensors and wiring are always used; otherwise inefficient or incorrect solar system operation may result.

3. Heat Transfer Liquid

Most of the systems are charged with a propylene glycol/water solution with corrosion inhibitors added. Where plumbing codes permit, ethylene glycol is sometimes used in conjunction with double wall heat exchangers.

The lower the temperature of the fluid in the loop and the lower the presence of oxygen, the better will be its physical and chemical stability. With elevated temperatures in the presence of free or dissolved oxygen, the oxidation process of the glycol solution is accelerated. This diminishes the effectiveness of the corrosion/oxidization inhibitors and also decreases the strength (freeze protection) of the anti-freeze.

The duration of the frost protection and corrosion protection qualities of the solution varies from system to system and among manufacturers.

Regular monitoring of the physical and chemical properties of the heat transfer liquid is essential to guarantee frost and corrosion protection. (See Operators' Guidelines, Section 10)

(A) Closed Loop System - cont'd

4. Instrumentation Guideline

The following instruments are necessary to perform routine basic inspections and to afford the detection of abnormal operating conditions.

(a) Pressure Gauge

The pressure gauge should be installed on the discharge of the circulating pump.

At this location, the pressure gauge can give two useful readings:

- with the pump off, the gauge will read system static pressure. (static head plus pressurization)
- with the pump running, the gauge will read system static pressure including pressurization, plus pump head.

The difference between the two readings will indicate the pump head.

The gauge can also be used (but not as a routine task) to establish whether there is system flow by manually shutting off any one valve installed on the main loop. This test is performed while the pump is running.

(A) Closed Loop System - cont'd

(a) Pressure Gauge- cont'd

Once the valve is shut, the pressure on the gauge should rise somewhat.

The gauge is used to initially charge and pressurize the closed loop. Under normal circumstances the pressure should not fall much below the initially established fill pressure when the system fluid cools down (at night, or on cloudy days).

Minimum system pressure (fill pressure) is established using the "temperature/pressure" graphs for the appropriate building height and volume of anti-freeze in the system.

As the temperature of the fluid in the closed loop increases, the system pressure increases.

A consistent relationship will exist between the closed loop fluid temperature and the system pressure. This relationship should be determined and recorded for comparison purposes during the commissioning of the installation. This relationship is more pronounced on large volume systems of higher buildings.

(A) Closed Loop System - cont'd

(a) Pressure Gauge- cont'd

If this relationship changes, there has been a change in the quantity of fluid contained in the closed loop. Fluid may have been lost through:

- the pressure relief valve
- the air vent
- the pump seals
- a leak in the piping system
- a leak in the heat exchanger
- defective expansion tank - water logged.

Fluid may have been gained from a leak in the heat exchanger where domestic water pressure exceeds the closed loop pressure.

If an unusually low pressure exists, (below established charge pressure), the system may not be pressurized relative to atmosphere at the top of the loop; a vacuum may exist and air entrainment is possible. In this case, fluid must be added and the system purged free of air.

If an unusually high pressure exists and the relief valve has discharged fluid, the reasons could be:

- fill pressure originally set too high
- pump not operating - collectors overheating with possible steam formation causing pressure build-up. (stagnation condition)
- no flow condition in closed loop
- expansion tank defective - water logged
- expansion tank too small for system
- system temperature unusually high, over-collection of solar heat - possible steam formation in collectors
- internal or external fouling of heat exchanger.

(A) Closed Loop System - cont'd

(b) Thermometer in Closed Loop

The temperature in the closed loop may vary between 3°C and 90°C. When the pump is operating the thermometer(s) in the loop will read fluid temperature; when the pump is off the thermometer(s) will stabilize to read room temperature. The difference in liquid temperature between collector feed and return will vary as follows:

> Since the same model and size pump is used to serve between 1 and 6 collectors, the temperature difference for a 2-collector system will be much smaller than that of a 6-collector system in unbalanced systems.
>
> At maximum solar incidence, a properly balanced system (nominal flow 4.0 L/s/min/2m^2 collector) will typically show a temperature difference of 5°C between collector feed and return.
>
> The average temperature difference on a sunny day will be less than half of that indicated for maximum solar incidence.

It is recommended that only one thermometer be installed in the closed loop, located at the discharge side of the pump in the collector feed line. For the purpose of routine inspection, this thermometer will indicate roughly the collector loop temperature.

(A) Closed Loop System - cont'd

(b) Thermometer in Closed Loop- cont'd

Experience has shown that commercially available liquid filled or bi-metallic thermometers are usually not calibrated, or kept in calibration, to sufficiently close tolerances and, unless a pair of closely matched thermometers are installed, the differential readings which would be obtained (0-6°C max.) on a thermometer having a range of 0-100°C will be meaningless or even misleading. It is recommended that a single thermometer be provided for each installation and that temperature measurements be conducted by inserting this instrument into strategic points of the system through Peterson plugs.

(c) Thermometer(s) in Secondary Circuit (Domestic Water)

The temperature of domestic water entering the solar storage tank will be that of the cold water supply source. The water inlet temperature may thus vary,depending on the source and time of year, between 1°C and 15°C. Depending upon the draw from domestic hot water system, the water temperature at the solar storage tank inlet will be that of room temperature, that of stored water temperature, or a temperature somewhere in between. For the purpose of routine inspection it is of no value to have knowledge of the water temperature at the inlet of the solar storage tank.

(A) Closed Loop System - cont'd

(c) Thermometer(s) in Secondary Circuit (Domestic Water) - cont'd

The water temperature at the outlet of the solar storage tank will indicate the highest level to which domestic water has been heated by the solar heating system.

During system commissioning, with domestic water supply stopped, a simple performance test on a sunny day would indicate the level to which the water in the tank has been heated by the solar system.

During normal operation, the temperature indicated at the solar storage tank outlet would be the level at which the solar heating system supplies water to the auxiliary tank heater or the tempering valve.

(d) Peterson Plugs

This device offers a practical solution to temporarily access various points in pressurized systems without loss of fluid. In combination with a single thermometer or portable electronic temperature probe, comparitive temperature readings can be taken. Caution should be used when soldering near Peterson plugs as the Nordel/Rubber seals in the device may sustain damage due to excessive heat.

(e) Flow Indicator in Closed Loop

A lack of flow in the closed loop circuit can lead to serious operational problems and eventual system failure and material damage.

(A) Closed Loop System - cont'd

(e) Flow Indicator in Closed Loop - cont'd

It is of great importance to ascertain on a regular basis whether circulation within the closed loop exists whenever solar heat at a useful temperature is collected. A lack of circulation with the pump running can be attributed to many causes:

- air in the system
- blockage at some point in the loop
- pump impeller defective, blocked or disengaged
- pump installed backwards
- part of circuit frozen.

It is recommended that a flow indicator be installed at a point in the closed loop piping system where ready access for regular observation is afforded.

Several types of suitable flow indicators are currently available. A number of these devices also act as check valves and could, in fact, elminate the need for a separate check valve.

Other types also indicate flow rate by means of a spring or gravity mechanism.

(f) Elapsed Time Indicator for Closed Loop Pump

Since the packaged solar heating systems are not inspected regularly by the technical personnel, the knowledge of pump run-time can provide to a non-technical individual reasonable indication as to whether the system, over a selected time period, has run too often or not often enough. This could reveal the following:

- system running too often or not often enough, due to control system problems or other deficiencies.

- system not running due to power off or control unit failure.

(g) Container for Overflow from Relief Valve

A container provided to hold and show overflow as a result of relief valve popping will give indication of the following:

- pump may have been off and collectors stagnated, forming steam
- fill pressure may have been set too high originally
- expansion tank too small for system volume
- expansion tank defective, water-logged.

(A) Closed Loop System - cont'd

(g) Container for Overflow from Relief Valve cont'd

It is recommended that a container with a minimum capacity of the packaged system anti-freeze volume be attached permanently to the discharge line of the closed loop relief valve. This same tank can be used for filling, mixing and drain-down for servicing purposes.

(h) High Temperature Indicator at Collector Outlet

If no flow exists through the collectors during periods of solar insolation, the temperatures of the collector plate and heat transfer liquid can reach excessive levels, leading to problems:

- Overheating of the heat transfer fluid, formation of steam and increase of pressure with possible loss of anti-freeze through relief valve and/or automatic air vent.
- A decrease in the strength of the anti-freeze, loss of frost protection.
- Diminishing effectiveness of the corrosion/oxidation inhibitor in the heat transfer fluid.

It is of great importance to know whether stagnation (overheating) has occurred. Such occurrences could be monitored with the application of some form of "highest reached" temperature recording.

(A) Closed Loop System - cont'd

(h) cont'd

Chemical temperature indicators are available in the form of small adhesive tapes which would indicate the highest temperature to which the collectors were subjected at some time in the past. It is recommended that chemical temperature indicators be attached at the outlet pipe of the collector bank and that a visual inspection be undertaken once each month, especially during the summer. Since the process of temperature indication is irreversible, the tape must be replaced whenever normal operating temperature limits have been exceeded. When it has become evident that safe temperature limits have been exceeded, the following could be concluded:

- Overheating due to power failure
- Lack of circulation
- Air in the System
- Control system malfunction
- Electrical power off
- Over-collection of solar energy.
- No Demand

(i) Temperature/Pressure Relief Valve at Solar Storage Tank

If a system is oversized in relation to the domestic hot water load, the temperature of the fluid in the closed loop and in the solar storage tank will rise excessively. The temperature/pressure relief valve installed in the solar storage tank usually is set at 75°C to 80°C and 860 kPa which will protect the domestic hot water circuit. Domestic water will be released to keep system temperature and pressure within these limits.

(A) Closed Loop System - cont'd

(i) High Temperature Indicator at Solar Storage Tank - cont'd

To monitor overflow due to excess temperature and/or pressure relief, a container should be permanently installed.

Where it is desirable to monitor maximum reached temperature at the solar storage tank, maximum-reached-temperature indicators, as described for the collectors, could be attached to the outlet pipe of the tank. Where chronic overheating occurs and domestic water is wasted to drain, it is recommended that the collector surface be reduced by means of reflective covers. Covering part of the collector area may be necessary only for part of the year.

(j) Automatic Freeze Protection

During certain outdoor conditions, parts of the closed loop containing the anti-freeze will be subjected to temperatures below 0°C. Provided that the strength of the anti-freeze is adequate, no damage will occur to this loop.

When the closed loop pump is in operation, heat is exchanged between the primary and secondary loops and it is possible, due to a malfunction in the control systems, for freezing to occur in the secondary system, causing the domestic water to freeze.

(A) Closed Loop System - cont'd

(i) Automatic Freeze Protection - cont'd

This situation cannot be prevented by regular inspection since it could arise at any time.

It is recommended that a strap-on automatic reset thermostat be installed on the discharge side of the pump, set at 35°F, to make inoperative the pump below this setting.

The concept of a strap-on temperature sensor would be beneficial since sufficient delay in temperature transmission is incurred to prevent nuisance cycling of this safety device upon start-up.

It is not recommended that the freeze protection be in any way tied in with the control system so that it may act as an independent control circuit.

PACKAGED

CLOSED LOOP

DOMESTIC HOT WATER SOLAR HEATING SYSTEM

TYPICAL SINGLE PUMP CONFIGURATION

Ⓣ THERMOMETER

■ PETERSON PLUG

Ⓟ PRESSURE GAUGE

⊡ FLOW INDICATOR

⋈ VALVE

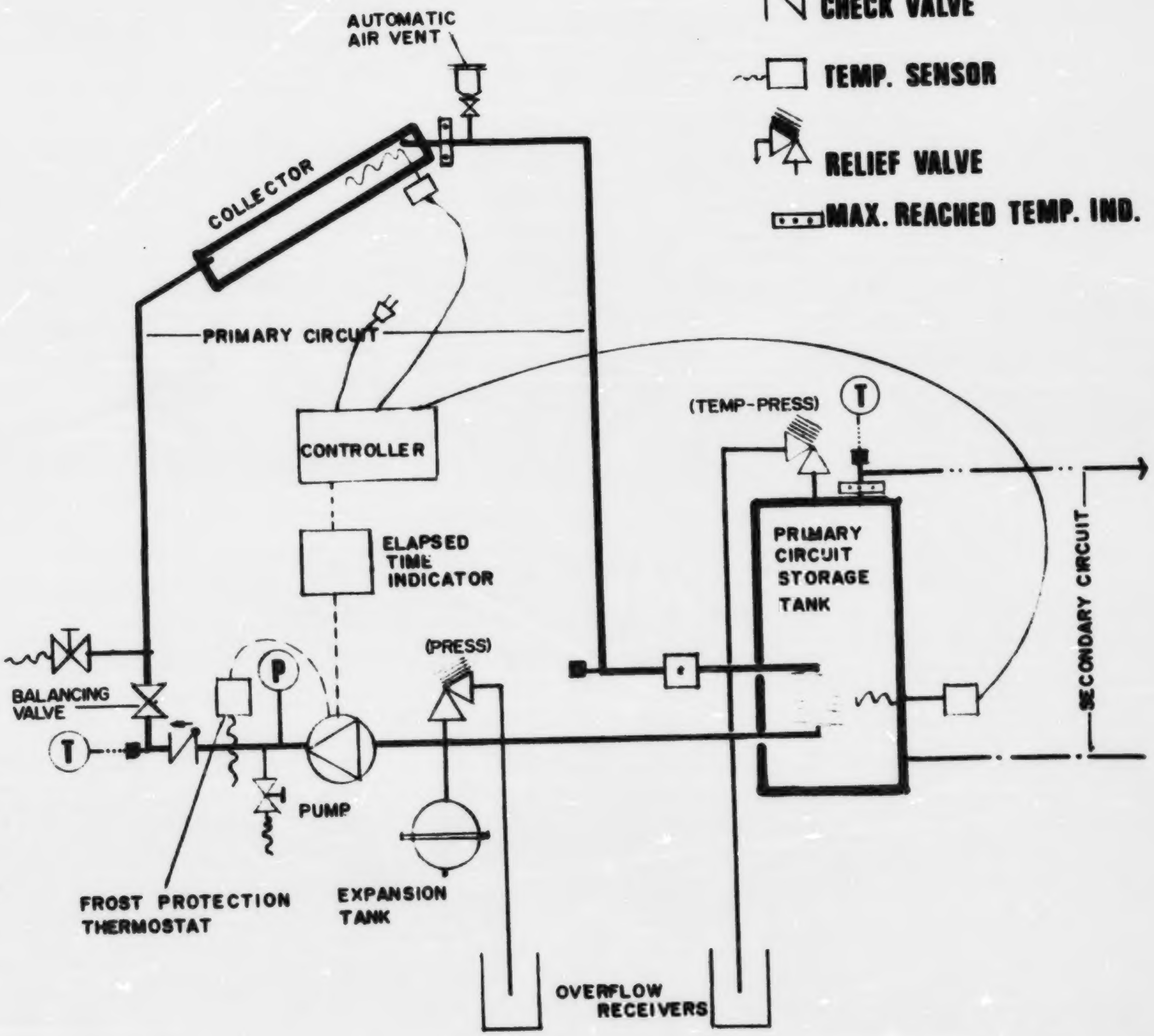
FILL VALVE / DRAIN VALVE

CHECK VALVE

TEMP. SENSOR

RELIEF VALVE

MAX. REACHED TEMP. IND.



PACKAGED

CLOSED LOOP

DOMESTIC HOT WATER SOLAR HEATING SYSTEM

TWO-PUMP SYSTEM

Ⓣ **THERMOMETER**

■ **PETERSON PLUG**

Ⓟ **PRESSURE GAUGE**

⊡ **FLOW INDICATOR**

⋈ **VALVE**

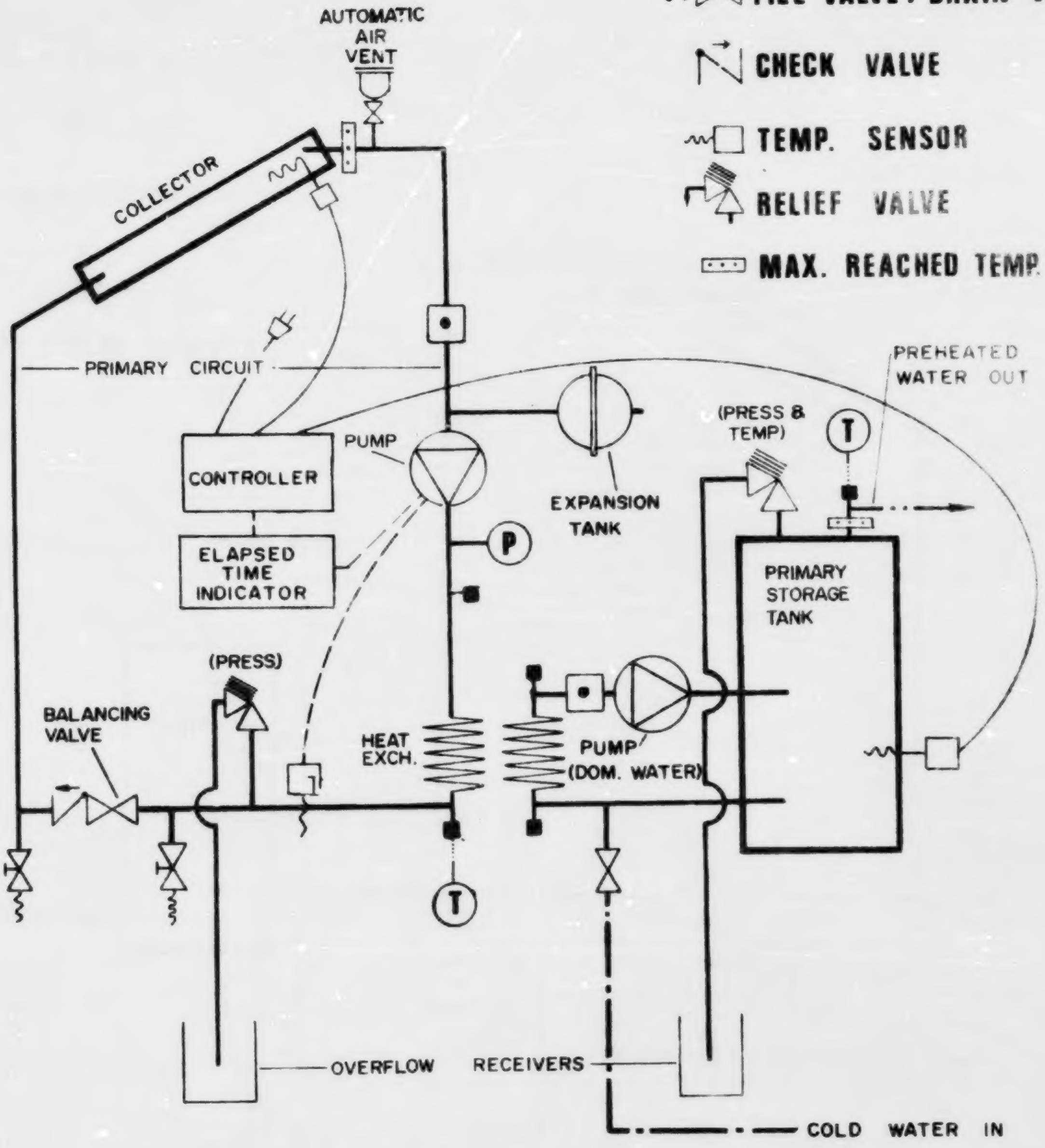
⋈ **FILL VALVE / DRAIN VALVE**

CHECK VALVE

□ **TEMP. SENSOR**

RELIEF VALVE

▭ **MAX. REACHED TEMP. IND.**



(A) Closed Loop System - cont'd

5. Provisions Made for Performance Verification

Provisions should be made in the pipe circuits for the purpose of performance verification, fine tuning, and trouble-shooting. These provisions should incorporate "points of access" suitable for measuring temperatures and flows with precision instruments.

Temperature

The provision of "Peterson" plugs for temperature measurement permits the use of probes with RTD, semi-conductor, thermistor, or thermocouple elements with diameters between 3mm and 4mm, or of a field supplied thermometer used to access multiple points.

The installation of Peterson plugs is recommended in collector feed and return lines (closed loop) and in the domestic water line leaving the storage tank.

For the two pump system, Peterson plugs should also be installed in the pumped secondary domestic water loop entering and leaving the heat exchanger.

Where Peterson plugs are used for occasional precision monitoring with electronic or mechanical thermometer probes, no special precautions are required since the seals are very reliable and very little fluid will be lost during insertion and removal of probes.

When the Peterson plug is not in use for monitoring purposes, a screw cap with seal is secured as a safety measure.

5. Provisions Made for Performance Verification - cont'd

Flow

It may be desirable to measure the flow of fluid in the closed loop with precision instruments and, perhaps through the use of flow integrators in conjunction with the temperature probes, to produce data to show energy output. This could be achieved in a relatively inexpensive fashion provided that drain and system shut-off valves are installed as indicated in diagram "CLOSED LOOP".

It is recommended that two 20mm valves with hose end, chain and cap be provided; one on each side of a 20mm gate valve. These valves would, in addition to serving as drain and fill valves, be suitable for connection to a portable flow meter. During flow measurement the gate valve would be closed and the flow meter would be connected via flexible hose to the drain/fill valves.

If it is desirable to measure flow in conjunction with the temperature rise through the secondary circuit, the portable flow meter could be connected to one of several outlets normally existing in the domestic hot water circuit:

- Drain valve at bottom of auxiliary tank heater
- Kitchen faucet
- Bath or shower faucets
- Outdoor hose bibb

During periods of instantaneous performance monitoring of the secondary circuit, the water would be discharged to a drain.

(A) Closed Loop System - cont'd

6. Operational Monitoring and Maintenance Procedures

The type and extent of instrumentation provided for operational monitoring is considered to be that necessary to furnish the operator with sufficient information to make routine diagnoses, to calibrate and adjust the controls, and to ensure annunciation of alarm conditions.

The "Operator's Check List" should be used to record operating conditions and to perform operational analyses. Certain modifications and amendments may be required to the check list in order to suit the actual system design concept. The frequency of use depends upon the complexity and performance record of the solar system.

The "Maintenance Schedule" separates the system into components and lists the recommended procedures and frequency of each maintenance task. This schedule may have to be expanded or altered in order to accommodate other design concepts or specific manufacturer's recommendations.

The Operational Problems Chart serves as an aid to system trouble-shooting.

The use of the "Operator's Check List" may help in the detection of operational problems. The "Operator's Guidelines" reflects system concepts illustrated in this manual and explains the operation of individual control and monitoring components. It will help the operator to properly control and monitor the system, to identify problems, and to perform the necessary corrective measures.

OPERATOR'S CHECK LIST

CLOSED LOOP - SOLAR HEATING PACKAGE SYSTEM

PROJECT: PACKAGE SYSTEM MANUFACTURER:

OPERATOR: MONTH: YEAR:

Date and Time of Day	Weather Conditions (Check One)			Approx. Outdoor Temp. °C	Power On Yes or No	Pump On Yes or No	Flow Yes or No	Solar Tank Temp °C	Loop Temp °C	System Press. kPa	Elapsed Time Hrs. and Tenths of Hrs.	Closed Loop Overflow Container (Wet/Dry)	Solar Storage Tank Overflow Container (Wet/Dry)	Maximum Reached Temp. at Collector °C	Visible Leaks Yes or No
	Sunny	Partly Sunny	Cloudy No Sun												

MAINTENANCE SCHEDULE - CLOSED LOOP PACKAGED DHW SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
Complete System	Operational Checklist	x	x	x		x	Initially more frequently, then as required.
COLLECTORS:							
Panels	Inspect for leaks, breakage, overheating panels. Examine absorber plates for signs of corrosion, flaking, discolouration.				x		On sunny days (pump running)
	Manage snow		x				As required by snow build up. Winter months only.
Glazing	Wash externally with warm soapy water.					x	More often if dirty.
Vents	Check and clear vent holes.					x	Also if chronic condensation is observed.
Supports/Mounting and Fasteners	Check structure, tighten bolts, inspect isolation pads, touch-up where corrosion is evident					x	
Piping	Inspect hangers and supports. Adjust, check pipe slopes					x	Resupport pipes if sagging
	Verify pipe jackets and insulation. Repair weatherproof jackets where necessary. Replace wet fibreglass insulation. Inspect for UV degradation of plastic pipe jackets.					x	
	Check pipe connections, inter-panel hose couplings & roof penetrations.					x	Use 95-5 solder for copper pipe repairs or manufacturer's suggested components for high temperature hose couplings.

MAINTENANCE SCHEDULE - CLOSED LOOP PACKAGED DHW SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
COLLECTORS: (cont'd)							
Control Modules	Verify wiring/connections and mounting of sensors				x		
EXPANSION TANK							
Diaphragm Type	Drain system. Check precharging. Replace with EPDM type if water-logged.					x	Usually 85 kPa or as specified.
PUMPS AND MOTOR CONTROLS							
Motors	Check amps, temperature, RPM Listen for vibration/noise. Lubricate.					x	Where applicable.
Seals	Check pump seals for vibration, noise or leakage.				x		As per manufacturer's recommendations. Replace if leaking
Impellers	Listen for noise. Measure developed pressure				x		
HEAT EXCHANGER	Measure & record pressure drop through convertor				x		If possible; otherwise check loop flow rate. Follow manufacturer's recommendations if cleaning is necessary.

MAINTENANCE SCHEDULE - CLOSED LOOP PACKAGED DHW SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
STORAGE TANKS	Inspect tank insulation					x	
	Inspect tanks for signs of leaking, corrosion or deformation.					x	Replace damaged tanks.
Probes & Sensors	Disconnect, clean and manually test if possible					x	Well-mounted units can be accessed externally.
PIPING ACCESSORIES							
Primary and Secondary Loops	Verify mounting, hangers and slopes. Check for leaks and damaged or wet insulation					x	Repair as required
Valves	Manually operate. Check for stem leaks etc. Inspect glands and seals. Verify that they are returned to balanced or normal (NO/NC) operating positions					x	Replace if necessary. Valves should have tags attached, stating their function & normal setting
Check Valves/ Vacuum Breakers	Open, clean and verify operation where possible. Check springs on spring-operated valves.					x	
Relief Valves	Inspect if outlet port & discharge pipe are clear. Manually operate levered type. Verify setting if adjustable.					x	Replace overflow container under outlet pipe (if present).
Air Vents	Ensure floats and seals are clean on serviceable units. Check that vent caps are loosely screwed on. Inspect for leaks.				x		Should be isolated by shut off valves after commissioning.

MAINTENANCE SCHEDULE - CLOSED LOOP PACKAGED DHW SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
PIPING ACCESSORIES (cont'd)							
Fluids	Check pressure. If necessary top up with specified solar anti-freeze solution.				x		Chronic loss of liquid indicates systel fault; check for leaks in pipes, valves and air vents.
	Inspect for presence of colour or suspended solids.			x			By observing flow indicator
	Measure strength, pH & alkalinity. Replace degraded fluid.					x	Important before winter season. See Operator's Guidelines. Also check if stagnation is suspected.
CONTROLS AND MONITORING INSTRUMENTATION							
Differential Controller	Verify correct system status indications for "OFF", "MANUAL" & "AUTOMATIC" control positions. Check that pumps are actually running per control indications.			x			
	Turn power off, then reset to verify controller start-up operation.			x			Preferably on sunny day.
	Measure controller "ON" & "OFF". temperature differentials. Adjust if necessary.					x	Certain controllers give direct electronic or digital readouts; others will require the placement of sensors in temperature baths to fully verify set points

MAINTENANCE SCHEDULE - CLOSED LOOP PACKAGED DHW SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
CONTROLS AND MONITORING INSTRUMENTATION (cont'd)							
Other Instruments	Check elapsed time meter, thermometer, pressure gauge & flow indicator for proper operation.			x			Repair/replace defective units.
Wiring (Power)	Check insulation near controllers, contactors & motors for signs of shrinking or brittleness. Inspect for physical damage of wire or conduit					x	Overheating of wire may be due to poor relay contacts, loose terminals or overloaded pump motor; check.
Wiring (Sensors)	Verify that junctions, protective conduits and shielding are intact. Loosen off and retighten terminal screws.					x	

OPERATIONAL PROBLEMS CHART

Comprehensive "Automatic Monitoring" is not considered viable for small domestic hot water packaged heating systems. The capital cost for the required instrumentation and installation would be greatly out of proportion with the capital costs for the packaged solar systems.

Regular ongoing operational monitoring on the basis of "Routine Inspection", however, is considered necessary to achieve efficient operation and to detect, as early as possible, any developing faults which otherwise could lead to serious breakdowns and material damage.

OPERATIONAL PROBLEMS

SOURCE OF PROBLEM	POSSIBLE CAUSES	CONSEQUENCES	PROTECTION	
			AUTOMATIC MONITORING	ROUTINE INSPECTION
PUMP: Failure to operate when required to.	- Power off, Blown Fuse or Tripped Breaker - Not started through controller - Motor burned out - Impeller seized, blocked or disconnected. - Electrical Problem * - Open cct.in collector sensor wiring * - Short cct.in storage tank sensor wiring.	- No collection of solar heat - Overheating of the transfer fluid - Steam build-up and loss of fluid - Stagnation Conditions: -Accelerated breakdown of antifreeze. -Corrosion -Frost damage	- Flow switch & alarm - High collector temperature alarm - Pump differential pressure alarm	- Observation of flow - Max.Collector temperature indication - Elapsed time indication
PUMP: Operating when not required to:	- Problem with sensors and/or controller - Faulty Switch - Faulty Wiring * - Closed cct.in collector sensor wiring * - Open cct.in storage tank sensor wiring	- Reverse heat exchange - Freeze-up of storage tank.	- Photo-electric lockout - Low limit alarm protection	- Elapsed run time indication - Thermometers - Observation of flow.
EXPANSION TANK:	- Water-logged - Insufficient size - Originally charged too high -(Fill pressure too high)	- Build-up of pressure - Transfer fluid relieved - Air entrainment - Loss of circulation - Pump overheat - motor seized - Stagnation Conditions: - Breakdown of anti-freeze. - Corrosion - Frost damage	- Hi/low press.alarm - Flow switch alarm	- Press.gauge - Observation of overflow tank.

* Applies to thermistor sensors

SOURCE OF PROBLEM	POSSIBLE CAUSES	CONSEQUENCES	PROTECTION	
			AUTOMATIC MONITORING	ROUTINE INSPECTION
CONTROLLER: Not operating correctly	- Not adjusted correctly - Sensors loose - Faulty wiring - Faulty electronics - Faulty switches	- Inefficiency - Stagnation Conditions: - Breakdown of anti-freeze. - Corrosion - Frost Damage	- Photo-electric lock out - Lo-Hi limit alarms	- Run time indication - Thermometers - Max.Collector temperature
CHECK VALVE: Stuck open	- Dirt/foreign matter in system	- Reverse flow due to gravity circulation - Inefficiency	- Solenoid valve opens when pump operates	- Observation of flow.
CHECK VALVE: Stuck Closed	- Dirt/foreign matter in system	- Reduced or no flow - Collector heat build-up - Damage to motor, seals, bearings - Stagnation and subsequent consequences (see above)	- High collector temperature alarm - Flow switch alarm - Pump differential pressure alarm	- Observation of flow - Max.Collector temperature indication
AIR VENT: Air in System	- Not venting - blocked	- Lack of circulation - Lack of heat collection - Pump overheating - Stagnation and resultant damage	- Flow switch alarm - Press. differential alarm - High collector temperature alarm	- Observation of flow - Max.Collector temperature indication. - Thermometers - Press.Gauges
NO CIRCULATION Pump Running	- System air locked - Leak in piping system (fluid lost) - Part of piping system frozen up - Blockage in piping system - Impeller or drive defective	- No collection of solar heat - Stagnation and subsequent consequences (see above) - Pump overheating	- Flow switch alarm - High collector temperature & alarm - Low pressure alarm - Current sensing of pump motor	- Observation of flow - Press.Gauge

SOURCE OF PROBLEM	POSSIBLE CAUSES	CONSEQUENCES	PROTECTION	
			AUTOMATIC MONITORING	ROUTINE INSPECTION
LEAK IN PIPING SYSTEM	- Incorrect solder joint - Expansion/contraction causing break - Frost damage - Corrosion	- Loss of system pressure - No collection of solar heat - Poor or no water circulation - Stagnation Conditions subsequent consequences - Pump Overheating	- Low Pressure Alarm - Flow Switch Alarm - High collector temperature alarm - Current Sensing of Pump Motor & alarm	- Visual Inspection - Observation of flow - Press.Gauge
FROST DAMAGE TO PRIMARY CIRCUIT	- Transfer fluid lost its freeze protection ability	- No flow - Break in piping circuit - Loss of fluid	- Can be prevented by regular check of quality of anti-freeze	- Regular check of quality of anti-freeze
FROST DAMAGE TO SECONDARY CIRCUIT	- System operation out of control - Sensor(s) have come loose - Controller or sensor defective - Electrical fault	- Reverse heat exchange - Frost damage to secondary system tank and pipes - Flooding	- Low Temp. Alarm and automatic pump cut-off	- Automatic pump cutoff and visual alarm
RELIEF VALVE Keeps popping	- Fill pressure too high - Defective relief valve - Expansion tank water-logged - Expansion tank too small for system	- Loss of fluid - Air entrainment - Lack of fluid circulation - Stagnation Conditions and subsequent consequences	- High Press. Alarm	- Observation of fluid discharged to drain tank - Press.Gauge
CROSS CONTAMINATION	- Leak in heat exchanger	- Loss of system pressure	- Low Press. Alarm	- Press.Gauge

OPERATOR'S GUIDELINES

1. POWER

Power should always be on; check fuse or breakers.

2. PUMP AND FLOW INDICATOR

If pump is on there should be flow. If there is no flow make sure that:

(a) Gate valve in closed loop is open.
(b) System is free of air; bleed air at top of collectors.

3. ELAPSED TIME METER

On a sunny day, the system should always have some run time. The number of hours that the system (pump) runs depends on:

(a) How much domestic hot water is drawn
(b) Hours of sunshine
(c) Time of year
(d) Outside temperature

The system may also run (cycle) on cloudy days or at night provided that the domestic water temperature entering the solar tank is much colder than the outdoor ambient temperature. Such run time, however, should be minimal. If the elapsed time meter shows excessive running (eg: more than 10 hours on a sunny day), a control problem may exist. Check if temperature sensors have come loose at collector or at storage tank.

If elapsed time meter shows no operation during sunny periods, check whether:

(a) Temperature sensors have come loose or detached at collector or storage tank.

(b) Freeze temperature setting is incorrect.

4. TEMPERATURE - CLOSED LOOP

Normally this temperature will vary between 2°C and 80°C depending upon:

(a) How much domestic water is drawn
(b) Hours of sunshine for day
(c) Time of year
(d) Outdoor temperature

If temperature exceeds 80°C there may have been no domestic hot water drawn for extended periods. There may be no flow and the thermometer, which is located near the pump, will indicate overheating.

If loop temperatures over 80°C are experienced regularly with normal flow, consider covering part of the collector surface. Excessive overheating will result in the temperature relief valve discharging domestic water to the waste container.

Excessive temperatures in conjunction with reduced or no-flow conditions in the loop may result in pressure build-up in the closed loop circuit and subsequent anti-freeze discharge; inform technical staff.

Consistent low temperatures on sunny days:

(a) Check whether controller set point is at automatic
(b) Check run time.
(c) Check whether part of collector bank is airlocked.

Note: Low temperature in closed loop may also reflect high domestic water draw; no action required.

5. SOLAR STORAGE TANK TEMPERATURE

This is the temperature to which the solar system has heated the domestic water.

6. OVERFLOW CONTAINER - CLOSED LOOP

During normal operation there should be no overflow. If fluid is present:

(a) Check closed loop temperature. If it has become excessive, see "Temperature-Closed Loop", Section 4.

(b) Check that system pressure is within limits after the system has cooled down.

7. OVERFLOW CONTAINER - SOLAR STORAGE TANK

Any overflow indicates excessive solar heat collection. If this condition persists, consider partial covering of the collectors during critical periods.

8. MAXIMUM TEMPERATURE INDICATION

Check at least once every month, and more frequently during hot summer months. Maximum reached temperature should not have exceeded 95°C. If there is evidence that this temperature has been exceeded contact the technical staff.

9. FREEZE PROTECTION THERMOSTAT

This instrument should be set at 2°C to 4°C; it protects the solar storage tank from frost damage and stops the pump. Upon start-up during very cold weather, the freeze thermostat may cycle the pump occasionally. If there is evidence of excessive cycling a control problem may exist -- contact the technical staff.

10. FREEZE PROTECTION ANTI-FREEZE

The adequacy of the strength of the anti-freeze must be verified each Fall before below-freezing temperatures occur.

10. FREEZE PROTECTION ANTI-FREEZE - cont'd

The adequacy of the strength and the corrosion protection (pH) must be verified after it has become evident that stagnation has occurred in the collectors. (Check maximum reached temperature indicator).

The pH (acidity) of both ethylene glycol and propylene glycol heat transfer fluids may be checked with limited range pH indicator tapes or with an electronic pH meter. The manufacturer's recommendations for specific anti-freeze solutions should be noted; normally acceptable pH values range from 7.5 to 9. The solutions should never be acidic (pH less than 7.0)

Determination of the strength of the anti-freeze solutions is quite different for ethylene glycol and propylene glycol mixtures and caution should be observed to ensure that the correct procedure is used in each case.

(a) Ethylene Glycol

Both the density (specific gravity) and the refractive index of ethylene glycol anti-freeze solutions change remarkably with respect to the glycol/water ratio. Thus a standard automotive hydrometer or other suitable temperature-compensated hydrometer can be used to verify the strength of the solution. At room temperature (16°C) a 50/50 ethylene glycol/water mixture has a specific gravity of approximately 1.07.

Another satisfactory method of determining the concentration of ethylene glycol anti-freeze mixtures is to use a portable refractometer; this is a direct-reading instrument which gives a 'freezing-point' indication based on the actual refractive index for the solution (See Instrumentation Guidelines, Section 8).

10. FREEZE PROTECTION ANTI-FREEZE - cont'd

(a) Ethylene Glycol - cont'd

The refractive index of a 50/50 ethylene glycol/water mixture at 25°C is approximately 1.384.

(b) Propylene Glycol

The densities of propylene glycol solutions are relatively insensitive with respect to the glycol/water ratio and special care is required if the anti-freeze strength is to be determined by a specific gravity method. It is important to note that a standard automotive hydrometer cannot be employed. A special, limited-range hydrometer covering specific gravities of 1.025 to 1.050, for example, may be used and the readings must be corrected for the fluid temperature. The specific gravity of a 50/50 propylene glycol/water mixture at 16°C should fall in the range of 1.038 to 1.045.

A straightforward method of determining the strength of propylene glycol anti-freeze solutions is to use a hand-held refractometer, as referred to in (a) above. When using the type with a "freezing point" scale it must be clearly marked that such a scale is for a propylene glycol mixture and not for an automotive anti-freeze. For an instrument with an actual refractive index scale, the expected reading for a 50/50 propylene glycol/water mixture at 25°C is 1.388.

Note: For further information about ethylene glycol and propylene glycol solutions see Solar Programs Office Technical Notes #6, 9, 14 and 21.

(A) Closed Loop System - cont'd

7. Recommended Instrumentation Specifications

1. Pressure Gauge

Equivalent to "Marsh" GP200; Range 0-700 kPa, 62.5mm diameter face, steel case black finished, complete with brass pet cock.

Contractor's Cost: $15.00

2. Thermometer

Equivalent to "Weksler" 1TO4C; Range -18°C to 150°C, 50.0mm diameter face, 3.5mm stem diameter, 100mm stem length, all stainless steel construction, bi-metal type.

Contractor's Cost: $25.00

3. Flow Indicator

Suitable for operating conditions of 100°C and 700 kPa; "RADA" Mechanical Products Ltd., Markham, Ontario, Rising Ball Type.

"TACO" Flow Setter. 3090 Lenworth Dr., Mississauga,Ont In-line flor meter, balancing valve,

"DRY-CON" Inc., 840 Halpern Ave., Dorval, Que, Dome Spinner type.

"HIGGINSON" Equipment Sales Ltd., Burlington, Ont., Bronze Flow Indicator.

"ARKON" Instruments Ltd., Ball type flow indicator also act as check valves; therefore the check valve, otherwise supplied, can be deleted.

"HEDLAND" EZ-View in-line flow meter, orifice/spring type. Brian Engineering Ltd., Kitchener, Ont.

"CALQFLOW" CF-450, orifice"gravity type. Blue White Industries, Westminster, California.

Contractor's Cost: $50.00

4. Elapsed Time Meter

Electro-mechanical, 110 volt, AC synchronous motordriven counter with non-resettable, 6-digit hour and tenths of hour indication, CSA approved. Equal to Bach Simpson #1357 ETIF.

Contractor's Cost: $50.00

(A) Closed Loop System - cont'd

7. Recommended Instrumentation Specifications - cont'd

5. Maximum Reached Temperature Indicators

Adhesive tape with chemical action, change of colour. Range: 80°C through 110°C in a minimum of four intervals.

- "Wahl" Temp-Plate recorder by Cole Palmer Scientific Instruments Ltd., or
- "Thermax" Range B by Thermographics Ltd., sold by Brian Engineering Ltd., Kitchener, Ont.

Contractor's Cost (each) $2.00

6. Freeze Protection Thermostat

Strap-on thermostat such as ALTEMP evaporator anti-icing unit, model AEIC1, opens at 1-3°C, 20 amps. 110VAC.

Contractor's Cost: $10.00

7. Peterson Plugs

Brass construction, 6.25mm NPT with 110-Nordel seal complete with brass cap and seal.

- Ontario Mechanical Sales, Downsview, Ont.
- R.C. Wall and Co., London, Ont.

Contractor's Cost (each): $9.00

8. Overflow Containers

Galvanized steel or plastic.

Contractor's Cost (each): $6.00

(A) Closed Loop System - cont'd

8. Instrumentation - Installed Costs - (based on 1983 rates)

1. **For Systems:**
   - Tempspec
   - Sun-Ray
   - Petro-Sun
   - Sol-Can

One	Pressure Gauge:	$ 15.00	
Two	Thermometers:	$ 50.00	
One	Flow Indicator:	$ 50.00	
One	Elapsed Time Meter:	$ 50.00	
	Wiring:	$ 5.00	
Two	Maximum reached Temp.Indicators:	$ 4.00	
One	Freeze Protection Thermostat:	$ 10.00	
	Wiring:	$ 5.00	
Three	Peterson Plugs:	$ 27.00	
Two	Overflow Containers:	$ 12.00	
	Total Material:	$228.00	$228.00
Labour:	Plumbing - 2.5 hrs.@ $25.00:	$ 62.50	
	Electrical-2.0 hrs.@ $25.00:	$ 50.00	
	Total Labour:	$112.50	$112.50
	Total Material and Labour:		$340.50
	Plus 10% Overhead:		$ 34.05
			$374.55
	Plus 10% Profit:		$ 37.46
	TOTAL INSTALLED COST:		$412.01

(A) Closed Loop System - cont'd

8. Instrumentation - Installed Costs - cont'd

2. For Two Pump System:

Materials as for above: plus:	$228.00	
Two Peterson Plugs:	$ 18.00	
One Flow Indicator:	$ 50.00	
Total Material:	$296.00	$296.00
Labour: as for others: plus:	$112.50	
1 hr. for plumbing @ $25.00:	$ 25.00	
Total Labour:	$137.50	$137.50
Total Material and Labour:		$433.50
plus 10% overhead:		$ 43.35
		$476.85
plus 10% Profit:		$ 47.69
TOTAL INSTALLED COST:		$524.54

3. Special Note

The cost estimates provided in the preceeding two sections reflect the expenditures which would be required to completely retrofit already-installed solar DHW package systems with the recommended operational monitoring instrumentation.

These costs could be reduced considerably by a number of factors:

(a) Most typical solar DHW package systems come complete with certain basic monitoring equipment -- this often includes 1-2 thermometers and pressure gauges and, in certain cases, a sight-flow indicator.

(b) Part of the cost for the recommended monitoring instrumentation involves the installation labour; for solar systems not yet in place this component could be made much smaller.

Plumbing: Time required during original installation of the valves, Peterson plugs and fittings is minimal.

(A) Closed Loop System - cont'd

8. Instrumentation - Installed Costs - cont'd

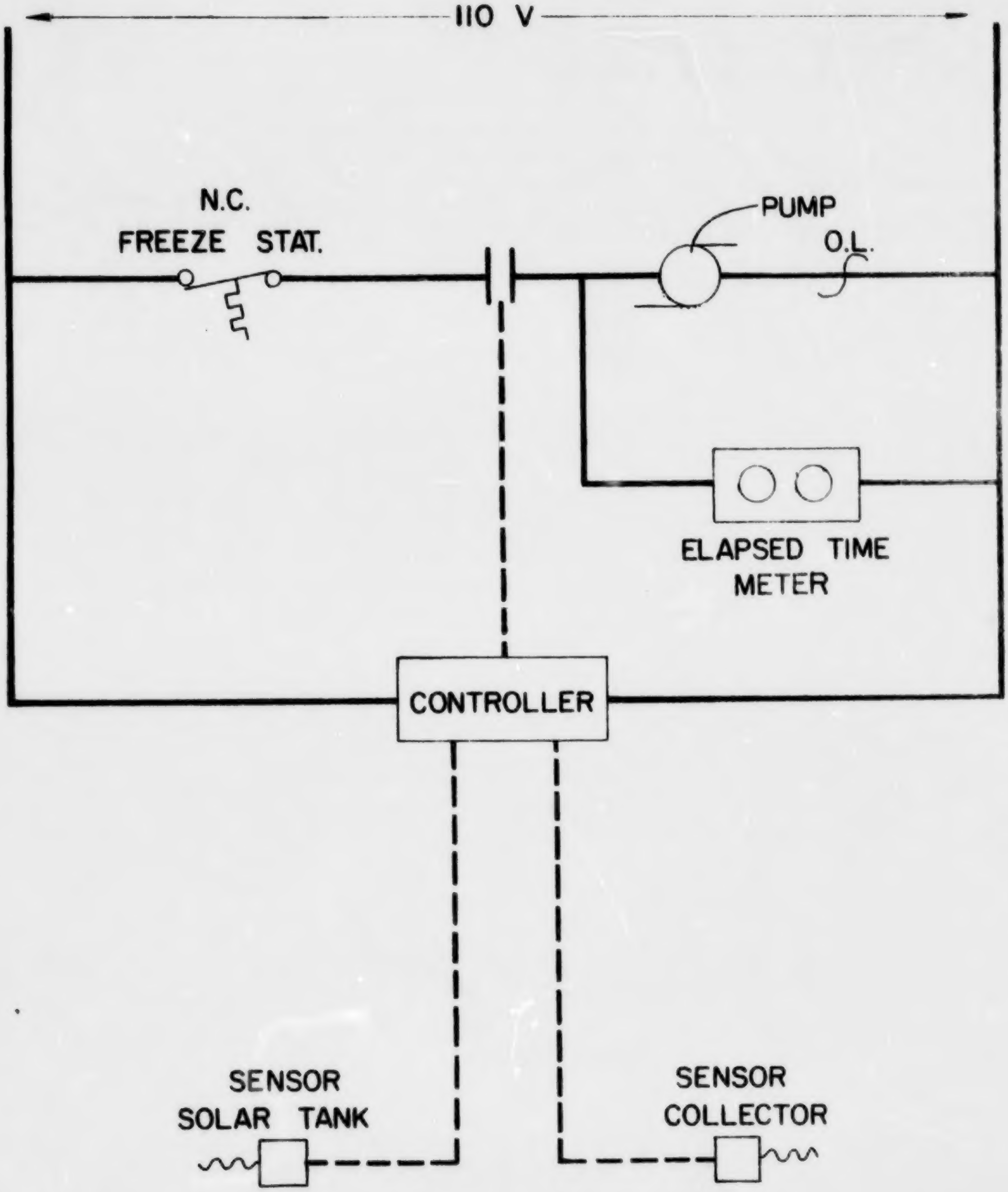
3. Special Note - cont'd

Electrical: If specified in the original order, certain simple modifications could be made by the manufacturers of the package systems to provide an elapsed-time meter and separate freeze protection unit within the main control panel. Another option would be the provision of plug-in outlets attached to the pump motor and power control circuits.

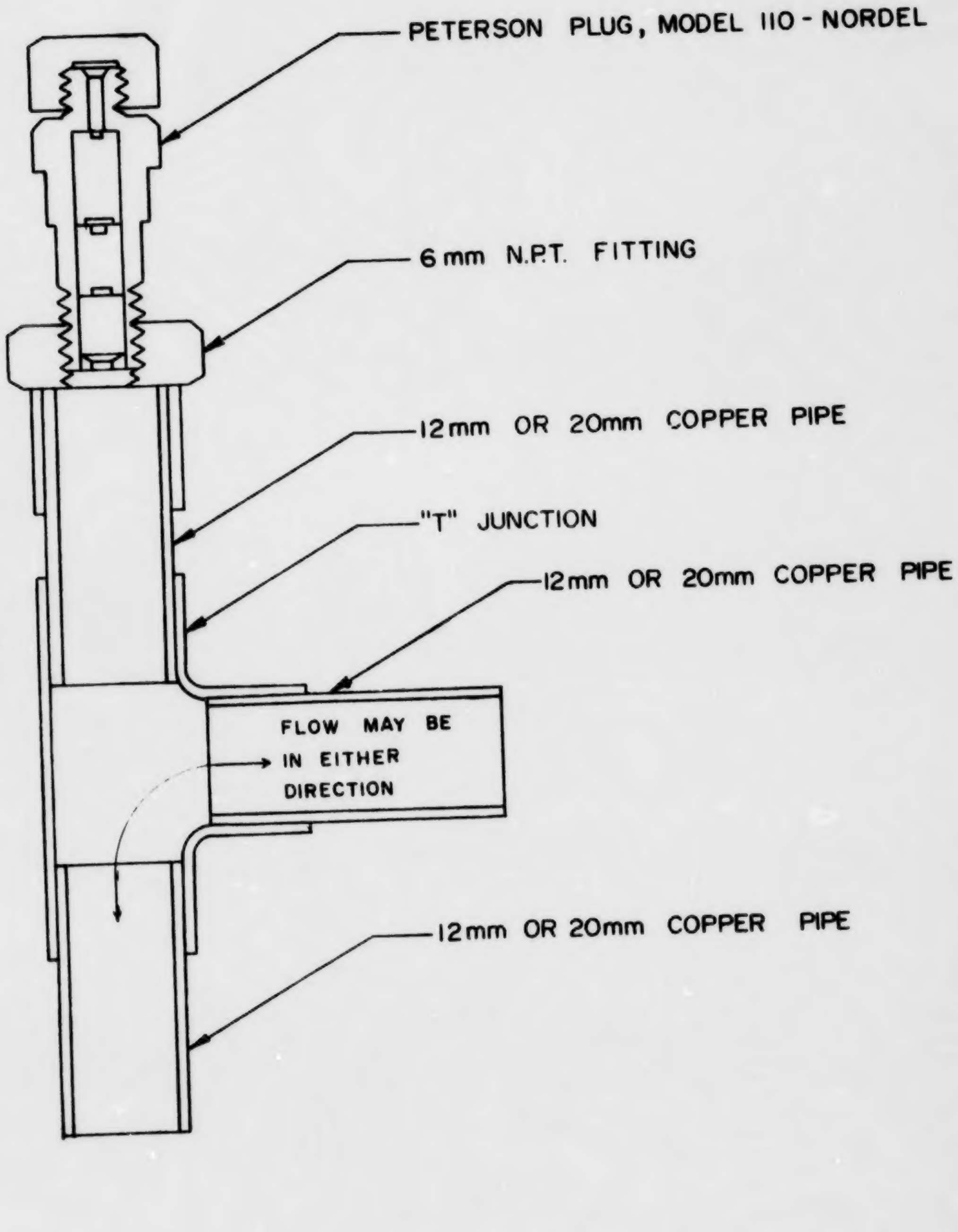
OEM: Prices used herein are quoted from local supply houses. Manufacturers will buy in quantity at OEM discounts at substantial cost reductions.

9. Refractometer - (for determining strength of anti-freeze)

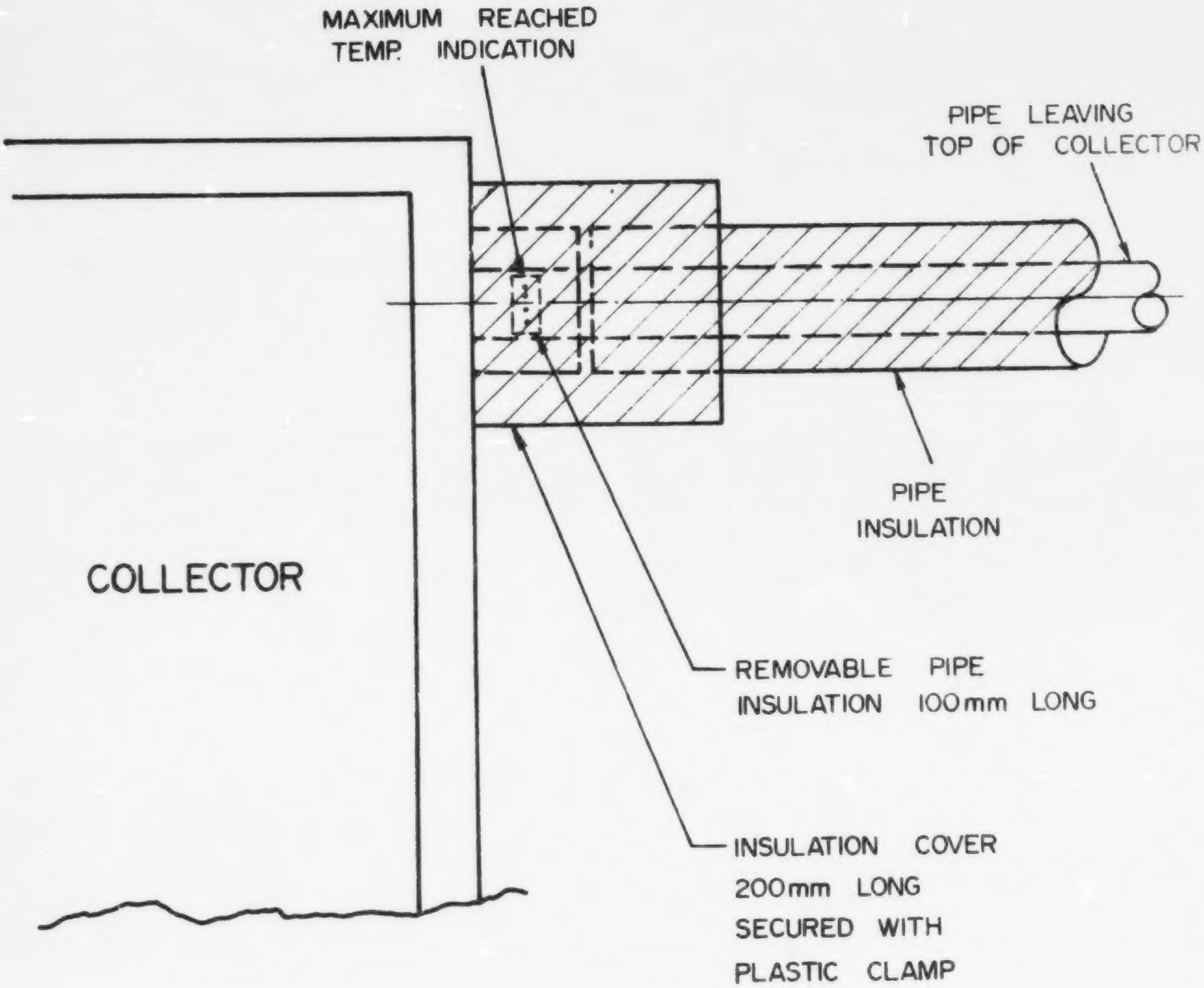
Equivalent to American Optical hand-held DUO-CHECK Model 7182, ordered with scale for propylene glycol and ethylene glycol as required (°C or °F). Available from Fisher Scientific Ltd. ($85.00)



ELECTRICAL WIRING DIAGRAM


PETERSON PLUG, MODEL 110 - NORDEL
6 mm N.P.T. FITTING
12 mm OR 20mm COPPER PIPE
"T" JUNCTION
12 mm OR 20mm COPPER PIPE
FLOW MAY BE IN EITHER DIRECTION
12 mm OR 20mm COPPER PIPE

INSTALLATION DETAIL PETERSON PLUG


MAXIMUM REACHED TEMP. INDICATION
PIPE LEAVING TOP OF COLLECTOR
PIPE INSULATION
COLLECTOR
REMOVABLE PIPE INSULATION 100mm LONG
INSULATION COVER 200mm LONG SECURED WITH PLASTIC CLAMP

MAXIMUM REACHED TEMPERATURE INDICATOR AT COLLECTOR OUTLET

OPERATIONAL MONITORING AND MAINTENANCE

PHASE 1 - SOLAR ASSISTED DOMESTIC HOT WATER PACKAGED SYSTEMS

DRAIN-BACK SYSTEMS

REVISED MARCH 1984

OPERATIONAL MONITORING AND MAINTENANCE

PHASE 1 SOLAR ASSISTED DOMESTIC HOT WATER PACKAGED SYSTEMS

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INTRODUCTION

The general concept of Operational Monitoring and Maintenance is to provide methods of ensuring:

- that the solar heating system is operating as designed.
- that operational problems and system breakdowns are detected as early as possible.
- that action is taken before serious damage and expensive repairs are incurred.
- that a long life expectancy of the system can be realized.
- that long-term operation and maintenance costs are kept to a minimum.
- that maintenance is performed on a regular, scheduled basis.

MONITORING STRATEGY

The methodology by which monitoring is accomplished for the packaged solar heating systems should take into account:

- that instrumentation essentially be kept basic and inexpensive,

- that routine inspection and simple diagnosis can be performed by non-technical individuals such as building maintenance staff,

- that operational check lists and maintenance schedules become part of a regular maintenance program,

- that simple corrective measures or other actions can be administered by non-technical individuals such as building maintenance staff,

- that simple records can be kept on a regular basis, useful for further examination and diagnosis by a technician, and

- that provisions are made in the system to facilitate the connection of precision instruments required for commissioning, fine tuning, trouble shooting, and performance verification by the technical staff.

OPERATIONAL MONITORING AND MAINTENANCE

PHASE 1 - SOLAR ASSISTED DOMESTIC HOT WATER PACKAGED SYSTEMS

DRAIN-BACK SYSTEM

TYPES OF SYSTEMS

Three different categories of solar-assisted domestic hot water packaged systems are described in publications issued by the Canadian Solar Industries Association, as follows:

(A) Closed Loop Systems
(B) Drain-back and Pressurized Drain-back Systems

This volume deals only with (B) Drain-back and Pressurized Drain-back Systems. The following systems fall into this category:

"Solarsystems"
(Solar Product Data Sheet #19)

"Petro Sun"
(Solar Product Data Sheet #25)

"Sol-Way"
(Solar Product Data Sheet #29)

"Solatherm" Pressurized Drain-back
(Solar Product Data Sheet #24)

"Nortec/Norsun" Seasonal Drain-Out
(Nortec Product Form US-03)

Solartech Model DBS-1-2, DBS-1-3 etc.

Sun-Ray Solar Systems Ltd. Models SR-DB-1,2,3

Drain-back and Pressurized Drain-back Heating System

1. General Description of Drain-back Systems

(a) The "Drain-back" domestic hot water system is a primary-secondary heating system.

The primary circuit herein referred to as the drain-back loop, consists of a pipe loop open to the atmosphere, connecting collectors with a primary circuit storage tank, herein referred to as the drain-back tank. The heating medium (transfer fluid) is water and is stored in the storage tank whenever the system is at rest. Whenever heat is available at a temperature suitable to effect domestic water heating, the drain-back pump is activated through a temperature differential controller. During this operation the water is pumped up to and through the collectors and drained back to the drain-back tank. After the heating cycle is completed, all suspended water runs back to the drain-back tank by gravity, through both the collector supply and collector return lines.

The drain-back tank is vented to atmosphere and contains a copper bundle heat exchanger or submerged tank heat exchanger. Heat is exchanged between the water contained in the drain-back tank and the domestic water which circulates through the copper bundle or submerged tank.

The pump installed in the drain-back loop is controlled by an ON-OFF temperature differential controller with sensors located at or near the outlet of the collector bank and at the domestic water tank. The pump is activated upon a temperature differential normally adjusted between 5°C and 15°C Δ T and is de-activated at a temperature differential normally adjusted between 1°C and 4°C Δ T.

(a) cont'd

In the case of the "Petro-Sun" drain-back system, the domestic water is circulated through the copper bundle heat exchanger by an additional pump activated in parallel with the drain-back loop pump. The heat sink is represented by an additional storage tank containing domestic water.

In the case of the "Solarsystems" drain-back system, the drain-back tank is oversized and acts, itself, as the heat sink. This concept requires no additional circulating pump in the domestic water circuit.

In the case of the "Sol-Way" drain-back system the drain-back tank surrounds the submerged heat exchanger tank and no additional circulating pump is required.

The drain-back solar heating systems are relatively safe with respect to cross-contamination between primary and secondary circuits. Since the domestic water pressure is substantially higher than the pressure in the drain-back tank, a leak in the heat exchanger would cause the domestic water to drain into the drain-back tank and overflow through the open vent to atmosphere. The circulator provided in the drain-back loop must be capable of providing a pump head to supply water to the top of the collectors.

(b) Heat Transfer Liquid

The heat transfer liquid contained in the drain-back loop is water. No chemicals are added for corrosion protection since all components forming part of the loop are copper. Water must be added to the systems periodically to make up for evaporative losses.

(b) Heat Transfer Liquid - cont'd

Most manufacturers recommend covering the surface of the water in the drain-back tank with a silicone oil film to reduce evaporation.

(c) Relief Valve to Protect Heat Exchanger - (Additional Requirements not shown in Manufacturer's Literature)

An additional pressure relief valve must be installed in the domestic water heat exchanger circuit. This would protect the heat exchanger circuit from excessive pressure build-up while the solar system is bypassed and isolation valves are manually closed for service or any other reason.

2. General Description of Pressurized Drain-back Systems

The pressurized drain-back system, as manufactured by "Solatherm" offers a direct heat exchange between the domestic water and the collectors, thus eliminating the need for a heat exchanger. Domestic water is circulated through the collectors whenever heat can be gained (as determined by the differential temperature controller sensing temperatures at the collectors and the storage tank). An air compressor maintains a cushion of air at the top of the storage tank to maintain a constant water level. The compressor is capable of maintaining a maximum pressure of 350 kPa (50 psig), consequently the city water pressure must be regulated at or below this point by means of a PRV installed in the incoming city water line.

When the pump stops, compressed air fills the collector feed and return lines and the collectors. A solenoid valve in the domestic water supply line automatically closes upon a high water level alarm or a power failure.

An additional check valve or solenoid may be required in the domestic hot water main where cross connections exist in valve trim or at appliance connections.

Since domestic water is heated in the solar collectors, the formation of calcium deposits could become a problem. Where the water hardness factor is above 40, the manufacturer does not recommend this system without the use of water softening equipment.

The control system differs from other drain-back systems in that two different pairs of temperature sensors are used to perform pump 'on-off' functions. In addition, the water level probe activates the air compressor, and an audible alarm annunciates a high water level and shuts off the solenoid valve(s) to isolate the solar loop from the domestic water circuit.

No schematic drawing has been included in this issue since minor changes to the package system concept are presently under consideration.

3. General Description of Seasonal Drain-Out System

This concept is most viable in areas with moderate climates and presupposes that the collector loop is drained out during months when freezing conditions prevail.

Domestic water passes directly through the solar collectors with the aid of a circulating pump, thus making a heat exchanger unnecessary. During the active season, pump control is effected by the standard differential temperature method. An additional temperature sensor, set at 3-5°C, is located one meter downstream of the collector outlet and ensures pump operation during near-freezing conditions.

3. General Description of Seasonal Drain-Out System - cont'd

The frost valve, a self-contained 'on-off' device located immediately ahead of the point where water returns to the heated space, opens if the water temperature approaches the freezing point. This is considered to add an additional safety margin in case of power failure; a steady water flow is ensured through the collector feed line and collectors.

In conjunction with the frost valve, the system check valve must be located in the collector return line near the tank to ensure a one-way flow during periods when the frost valve is open.

Since domestic water is heated in the collectors, calcium deposits within the collector tubes may be a problem in regions which have hard water. A water softener may be required depending upon the manufacturer's recommendations.

4. Instrumentation Guideline

The following instruments are necessary to perform routine checks and to afford the detection of abnormal operating conditions.

(a) Thermometer in Drain-Back Loop

The temperature of the fluid in the drainback loop normally may vary between 10°C and 90°C. When the pump is operating the thermometer(s) in the loop will read fluid temperature; when the pump is off the thermometer(s) will stabilize to read room temperature.

The temperature differential between collector feed and return varies between system installations and the amount of insolation (solar energy absorbed).

> At maximum solar incidence, a properly balanced system (nominal flow 4.0 L/s/min/$2M^2$ collector) will typically show a temperature difference of 5°C between collector feed and return.
>
> The average temperature difference on a sunny day will be less than half of that indicated for maximum solar incidence.

Experience has shown that commercially available liquid filled or bi-metallic thermometers are usually not calibrated, or kept in calibration to sufficiently close tolerances, and, unless a pair of closely matched thermometers are installed, the differential readings obtained (0-6°C max.) with thermometers having a range of 0-100°C will be meaningless or even misleading to the 'operator'.

4. Instrumentation Guideline - cont'd

(a) Thermometer in Drain-Back Loop - cont'd

It is recommended that only one thermometer be installed in the collector loop, located at the discharge side of the pump in the collector feed line or in the drainback tank. For the purpose of routine inspection, this thermometer will indicate roughly the collector loop temperature.

(b) Thermometers in Domestic Water Supply and Return

Knowing the temperature of the water in the domestic water heating circuit would be of little value to the "Operator" under normal conditions.

In the case of the "Solarsystem" and the "Sol-Way" packages, the temperature of the domestic water entering the heat exchanger would be that of the cold water supply source. The water inlet temperature may thus vary, between 1°C and 15°C, depending on the source and the time of year. The temperature on the outlet of the heat exchanger will vary according to the rate of domestic hot water drawn through the heat exchanger and the mean temperature of solar heated and stored water.

In the case of the "Petro Sun" system, the temperature of the domestic water entering the heat exchanger would vary between the temperature of the solar heated and stored water and that of the cold water source, depending on the rate of domestic water drawn. The domestic water temperature leaving the heat exchanger would normally be 1°C to 6°C higher than the temperature of the water entering the heat exchanger.

4. Instrumentation Guideline - cont'd

(b) Thermometers in Domestic Water Supply and Return-cont'd

The provision of thermometers in the domestic water circuit for the purpose of routine performance monitoring is not recommended.

(c) Flow Indicator in Drain-Back Loop

A lack of flow through the drain-back loop during hours of sunshine would render the system totally ineffective. It is of great importance to ascertain on a regular basis whether circulation within the drain-back loop exists whenever solar heat at a useful temperature is absorbed by the collectors. A lack of flow can be attributed to several causes:

- Blown fuse or tripped circuit breaker.
- Controller switched off.
- Open circuit or short circuit in control wiring to temperature sensor(s).
- Blockage at some point in the loop.
- Pump impeller defective, blocked or disengaged.
- Part of circuit frozen.

It is recommended that flow indicators be installed at a point in the drain-back loop piping system where ready access for regular observation is afforded. For the "Petro Sun" system it is recommended that flow indicators be provided in both the drain-back loop and the pumped domestic water loop. "Rising ball" and certain "Vane" type flow indicators are to be avoided on drain-back systems since this type also acts as a check valve.

The "CALQFLOW" flow meter has been successfully modified not to act as a check valve. Some package systems now use this instrument and others, both as a level indicator and a flow measuring device. This is accomplished by positioning the units vertically, just opposite the normal 'drain-back level' of the tank.

4. Instrumentation Guideline - cont'd

(d) Pressure Gauge

The provision of a pressure gauge for the drain-back loop is unnecessary since circulation can be observed by means of the flow indicator. The pressure gauge may be useful, however, for start-up and trouble shooting purposes. During start-up, the gauge would show how pressure builds up as the collector feed line fills with water. As the return line starts to drain water back to the tank, the pressure will reduce due to syphon action.

The pump head would then stabilize at a point where it develops the combined pressure to overcome pipe friction and a small amount of static head.

It is recommended that provisions be made in the form of a connection at the discharge side of the pump, complete with pet cock, suitable for the installation of a pressure gauge to be used by the technical staff for start-up and trouble shooting etc.

(e) Freeze Protection

A properly installed drain-back system could freeze up only if abnormal pump operation and cycling occurs at below 0°C collector temperature conditions. This could be due to a control system malfunction, a short circuit in the wiring to the temperature sensor at the collector, an open circuit to the wiring to the sensor at the storage tank, a defective controller, or the accidental setting of the controller to "Manual".

4. Instrumentation Guideline - cont'd

(e) Freeze Protection - cont'd

The provision of a freeze protection thermostat is recommended, complete with manual reset, with remote bulb installed in the collector return line at the drain-back tank. This device would be set at 5°C and wired in series with the pump motor.

It is not recomended that the freeze protection be in any way tied in with the control system so that it may act as an independent control circuit.

(f) Drain-Back Tank with Level Indicator

The solar system packages are equipped with a sight glass (clear plastic tube) mounted vertically adjacent to the drain-back tank, or with other type of visual level indication.

Water must be added through the fill valve periodically to make up for evaporative losses. If the water level drops significantly in a short period of time, a leak may exist in the drain-back loop. If the water level is increasing and water overflows, a leak may exist in the heat exchanger.

(g) Elapsed Time Indicator for Drain-Back Loop Pump

Since the packaged solar heating systems are not inspected regularly by the technical personnel, the knowledge of pump run-time can provide to a layman reasonable indication as to whether the system, over a selected time period, has run too often or not often enough.

4. Instrumentation Guideline - cont'd

(g) Elapsed Time Indicator for Drain-Back Loop Pump - cont'd

This could reveal the following:

- System running too often due to control system problems
- System not running due to power off or control system problems.
- System not running - collectors covered with snow, etc.

(h) High Temperature Protection

Some drain-back system manufacturers offer as standard equipment, or as standard optional equipment, high temperature protection to limit the fluid temperature of the drain-back loop to 90°C.

Overheating of the water in some drain-back loops and the formation of steam becomes possible during periods of "over-collection" during week-ends or holiday periods when the demand for domestic hot water is greatly reduced. High temperature protection is accomplished electronically through the control system and the storage tank temperature sensor with a pre-set reference level.

It is recommended that all systems be equipped with a high temperature cut-out as a standard feature.

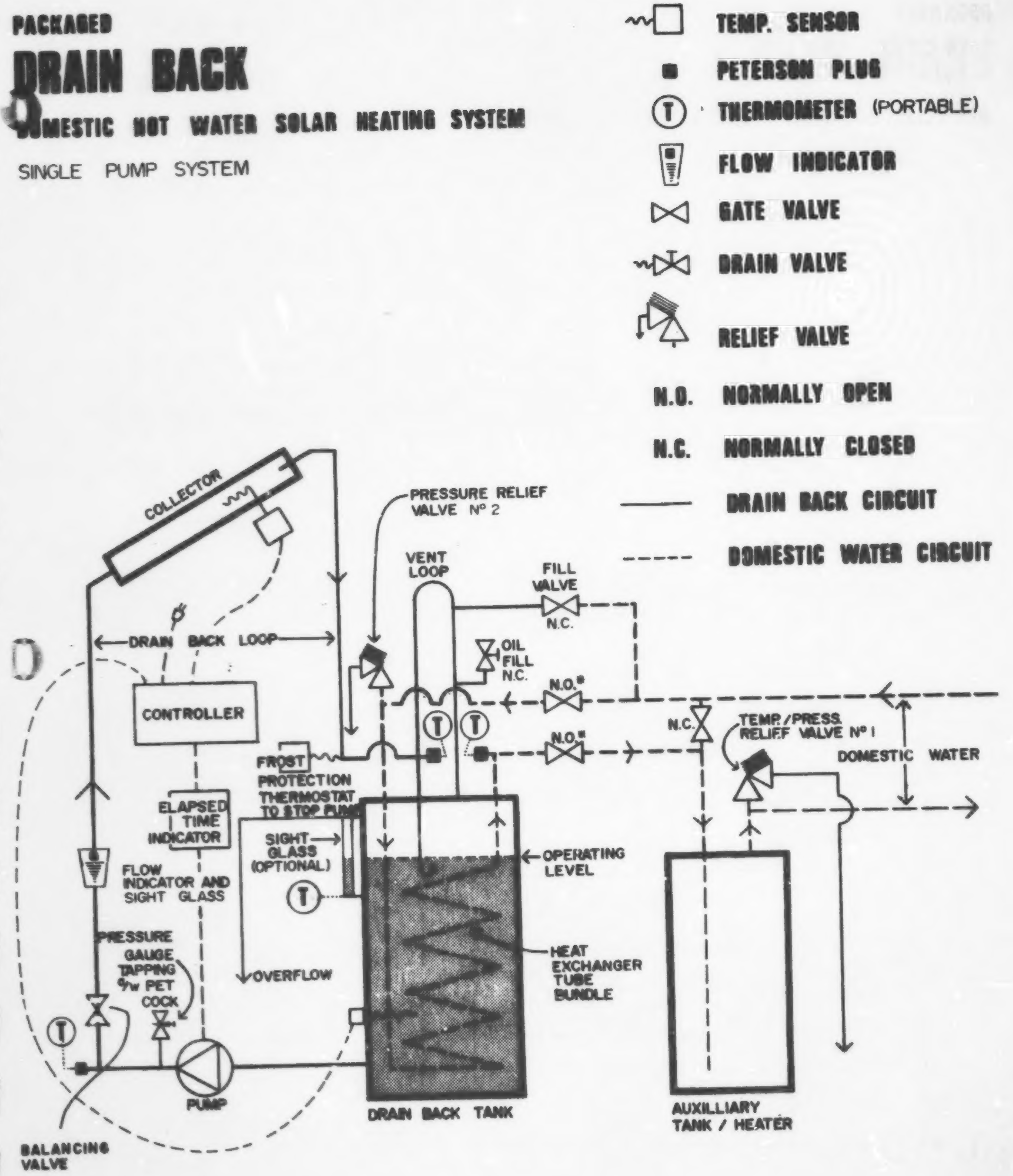
Certain types of collectors are subject to damage due to thermal shock and manufacturers recommendations must be followed regarding restarting systems following high limit shut-down.

PACKAGED

DRAIN BACK

DOMESTIC HOT WATER SOLAR HEATING SYSTEM

SINGLE PUMP SYSTEM



* IF BOTH ISOLATING VALVES ARE INSTALLED THE PRESS. RELIEF VALVE N°2 IS REQUIRED

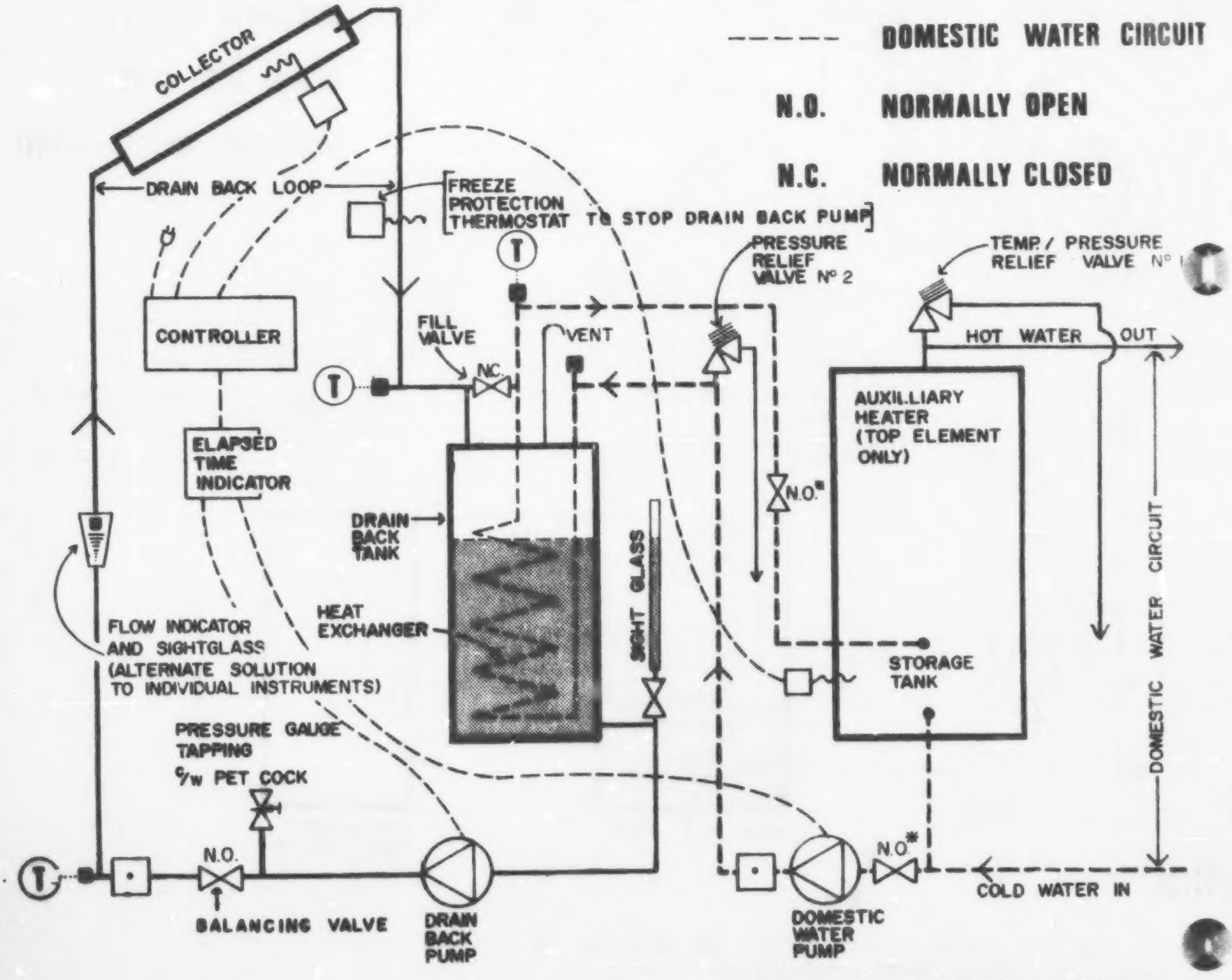
PACKAGED

DRAIN BACK

DOMESTIC HOT WATER SOLAR HEATING SYSTEM

TWO - PUMP SYSTEM

~☐	**TEMP. SENSOR**
■	**PETERSON PLUG**
Ⓣ	**THERMOMETER** (PORTABLE)
⊡	**FLOW INDICATOR**
⋈	**GATE VALVE**
~⋈	**DRAIN VALVE**
	RELIEF VALVE
——	**DRAIN BACK CIRCUIT**
- - - - -	**DOMESTIC WATER CIRCUIT**
N.O.	**NORMALLY OPEN**
N.C.	**NORMALLY CLOSED**

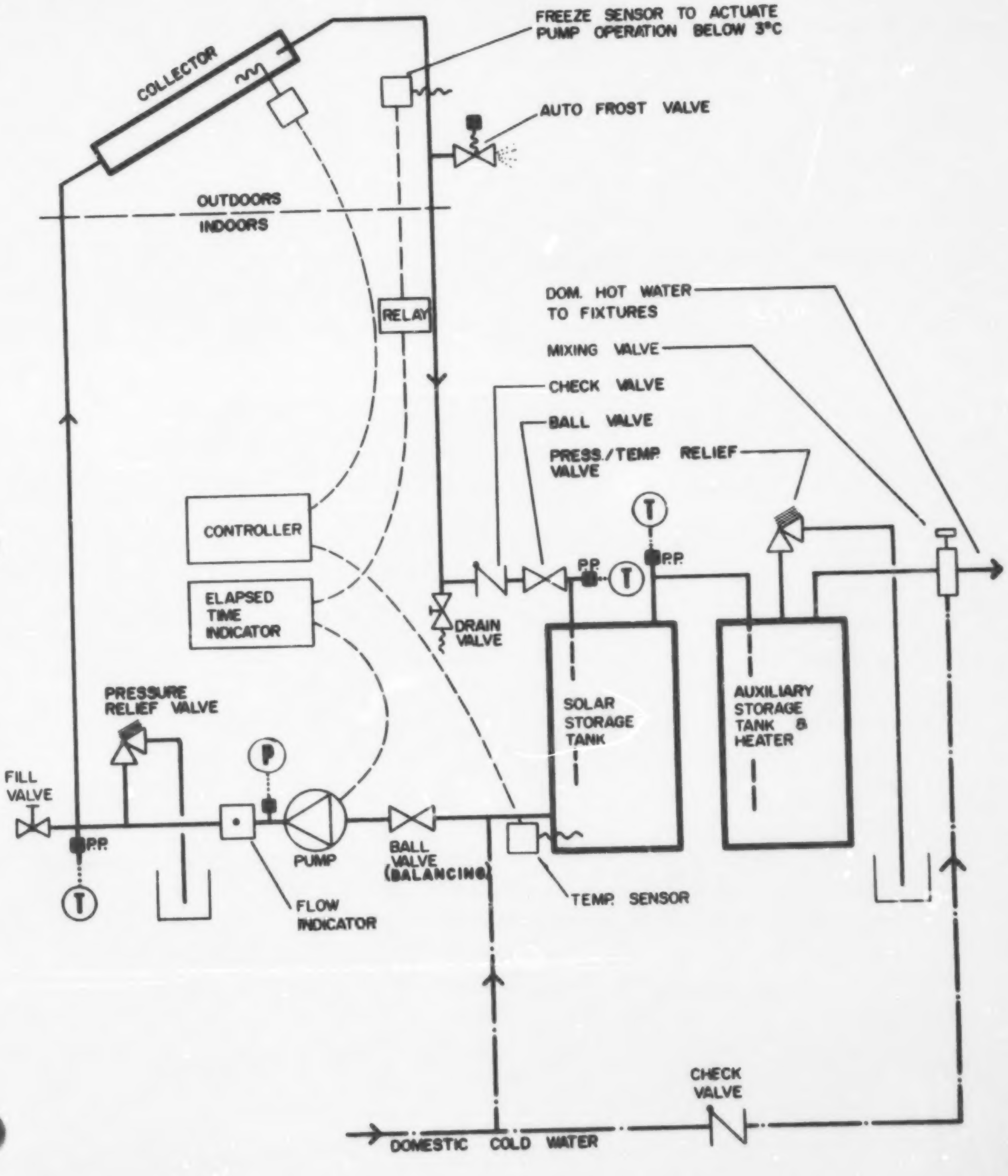

COLLECTOR
DRAIN BACK LOOP
FREEZE PROTECTION THERMOSTAT TO STOP DRAIN BACK PUMP
CONTROLLER
ELAPSED TIME INDICATOR
T
FILL VALVE
NC
VENT
PRESSURE RELIEF VALVE Nº 2
TEMP / PRESSURE RELIEF VALVE Nº 1
HOT WATER
OUT
AUXILLIARY HEATER (TOP ELEMENT ONLY)
N.O.*
DRAIN BACK TANK
HEAT EXCHANGER
SIGHT GLASS
STORAGE TANK
DOMESTIC WATER CIRCUIT
FLOW INDICATOR AND SIGHTGLASS (ALTERNATE SOLUTION TO INDIVIDUAL INSTRUMENTS)
PRESSURE GAUGE TAPPING c/w PET COCK
N.O.
BALANCING VALVE
DRAIN BACK PUMP
DOMESTIC WATER PUMP
N.O.*
COLD WATER IN

*PRESSURE RELIEF VALVE Nº2 IS MANDATORY IF THESE SHUT-OFF VALVES ARE INSTALLED

PACKAGED

RECIRCULATING SEASONAL DRAIN OUT

DOMESTIC HOT WATER SOLAR HEATING SYSTEM



P.P. = PETERSON PLUG

5. Provisions Made for Performance Verification

Provisions should be made in the pipe circuits for the trouble-shooting. These provisions should incorporate "points of access" suitable for measuring temperatures and flows with precision instruments.

Temperature

The provision of "Peterson" plugs for temperature measurement permits the use of probes with RTD, semi-conductor, thermistor, or thermocouple elements with diameters between 3mm and 4mm, or of a field supplied thermometer used to access multiple points.

The installation of Peterson plugs is recommended in collector feed and return lines (drain-back loop) and at points in the domestic water circuit indicated on the schematic diagrams.

Where Peterson plugs are used for occasional monitoring with electronic probes or thermometers, no special precautions are required since the seals are very reliable and very little fluid will be lost during insertion and removal of probes. When the Peterson plug is not in use for monitoring purposes, a screw cap with seal is secured as a safety measure.

Flow

It may be desirable to measure the flow of fluid in the drain-back loop with precision instruments and, perhaps through the use of flow integrators in conjunction with the temperature probes, to produce data to show energy output.

5. **Provisions Made for Performance Verification** - cont'd

If such energy monitoring is anticipated, it is recommended that two 20mm valves with hose end, chain and cap be provided; one on each side of a gate valve. These valves would be suitable for connection to a portable flow meter. During flow measurement the gate valve would be closed and the flow meter would be connected via flexible hose to the drain valves. In the case of the "Solarsystems" package, the gate valve and one drain valve already exist. Caution must be exercized when measuring flow at the suction side of the pump to ensure that no cavitation occurs.

The maximum pressure drop through the flow meter should be restricted to 3.5 kPa at a flow of 25 L/min.

In the case of the "Petro Sun" and "Sol-Way" packages, a gate valve and two drain valves should be added to the discharge side of the pump. The static head existing at the suction side of the pump would be insufficient to prevent cavitation due to the low height of the storage tank.

If it is desirable to measure flow in conjunction with the temperature rise through the domestic water circuit, the portable flow meter could be connected to one of several outlets normally existing in the domestic hot water circuit:

- Drain valve at bottom of auxiliary tank heater
- Kitchen faucet
- Bath or shower faucets
- Outdoor hose bibb

During periods of instantaneous performance monitoring of the secondary circuit, the water would be discharged to a drain.

6. Operational Monitoring and Maintenance Procedures

The type and extent of instrumentation provided for operational monitoring is considered to be that necessary to furnish the operator with sufficient information to make routine diagnoses, to calibrate and adjust the controls, and to ensure annunciation of alarm conditions.

The "Operator's Check List" should be used to record operating conditions and to perform operational analyses. Certain modifications and amendments may be required to the check list in order to suit the actual system design concept. The frequency of use depends upon the complexity and performance record of the solar system.

The "Maintenance Schedule" separates the system into components and lists the recommended procedures and frequency of each maintenance task. This schedule may have to be expanded or altered in order to accommodate other design concepts or specific manufacturer's recommendations.

The Operational Problems Chart serves as an aid to system trouble-shooting.

The use of the "Operator's Check List" may help in the detection of operational problems. The "Operator's Guidelines" reflects system concepts illustrated in this manual and explains the operation of individual control and monitoring components. It will help the operator to properly control and monitor the system, to identify problems, and to perform the necessary corrective measures.

OPERATOR'S CHECK LIST

DRAIN-BACK SYSTEMS

PACKAGE SYSTEM MANUFACTURER:

PROJECT:

MONTH: YEAR:

OPERATOR:

Date and Time of Day	Weather Conditions (Check One)			Approx. Outdoor Temp. °C	Power On Yes or No	Drain-Back Loop Pump On Yes or No	Dom. Water Pump On Yes or No	Drain-Back Loop Flow Yes or No	Dom. Water Loop Flow Yes or NO	Loop Temp °C	Elapsed Time Hrs.and Tenths of Hrs.	Visible Leaks Yes or No	Water Added Yes or No
	Sunny	Partly Sunny	Cloudy No Sun										

MAINTENANCE SCHEDULE - DRAIN-BACK PACKAGED DHW SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
Complete System	Operational Checklist	x	x	x		x	Initially more frequently, then as required.
COLLECTORS:							
Panels	Inspect for leaks, breakage, overheating panels.				x		On sunny days (pump running)
	Manage snow		x				As required by snow build up. Winter months only.
Glazing	Wash externally with warm soapy water.					x	More often if dirty.
Vents	Check and clear vent holes.					x	Also if chronic condensation is observed.
Supports/Mounting and Fasteners	Check structure, tighten bolts, inspect isolation pads, touch-up where corrosion is evident					x	
Piping	Inspect hangers and supports. Adjust, check pipe slopes					x	Resupport pipes if sagging
	Measure drain-back time.				x		Particularly important before winter season.
	Verify pipe jackets & insulation. Repair weatherproof jackets where necessary. Replace wet fibreglass insulation. Inspect for UV degradation of plastic pipe jackets.					x	
	Check pipe connections, inter-panel hose couplings & roof penetrations.					x	Use 95-5 solder for copper pipe repairs or manufacturer's suggested components for high temperature hose couplings.

MAINTENANCE SCHEDULE - DRAIN-BACK PACKAGED DHW SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
COLLECTORS: (cont'd)							
Control Modules	Verify wiring/connections and mounting of sensors				x		
DRAIN-BACK RECEIVER	Check water levels. Replenish with tap water.			x		x	
	Clean, descale, remove sediment and flush.					x	Including probes. Only if sediment build-up is significant.
	Inspect tank insulation. Verify anti-evaporation oil film. Add if necessary					x	As per manufacturer's recommendations.
PUMPS AND MOTOR CONTROLS							
Motors	Check amps, temperature, RPM Listen for vibration/noise. Lubricate.					x	Where applicable.
Seals	Check pump seals for vibration, noise or leakage.				x		As per manufacturer's recommendations. Replace if leaking
Impellers	Listen for noise. Measure developed pressure or flow.				x		
HEAT EXCHANGER	Measure & record pressure drop through convertor				x		If possible; otherwise check loop flow rate. Follow manufacturer's recommendations if cleaning is necessary.

MAINTENANCE SCHEDULE - DRAIN-BACK PACKAGED DHW SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
STORAGE TANKS	Inspect tank insulation					x	
	Inspect tanks for signs of leaking, corrosion, deformation or melting.					x	Replace or repair damaged tanks.
Probes & Sensors	Disconnect, clean and manually test if possible					x	Well-mounted units can be accessed externally.
PIPING ACCESSORIES							
Primary and Secondary Loops	Verify mounting, hangers and slopes. Check for leaks and damaged or wet insulation					x	Repair as required
Valves	Manually operate. Check for stem leaks etc. Inspect glands and seals. Verify that they are returned to balanced or normal (NO/NC) operating positions					x	Replace if necessary. Valves should have tags attached, stating their function & normal setting
Check Valves/ Vacuum Breakers	Open, clean and verify operation where possible. Check springs on spring-operated valves.					x	
Relief Valves	Inspect if outlet port & discharge pipe are clear. Manually operate levered type. Verify setting if adjustable.					x	Replace overflow container under outlet pipe (if present).
Air Vents	Ensure floats and seals are clean on serviceable units. Check that vent caps are loosely screwed on. Inspect for leaks.				x		Not present in many drain-back systems.

MAINTENANCE SCHEDULE - DRAIN-BACK PACKAGED DHW SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
PIPING ACCESSORIES (cont'd)							
Fluids	Check level. Top up with tap water.				x		Evaporative losses should normally be small.
	Inspect for presence of colour or suspended solids.			x			By observing flow/level indicator.
CONTROLS AND MONITORING INSTRUMENTATION							
Differential Controller	Verify correct system status indications for "OFF", "MANUAL" & "AUTOMATIC" control positions. Check that pump(s) are actually running per control indications.			x			
	Turn power off, then reset to verify controller start-up operation.			x			Preferably on sunny day.
	Measure controller "ON" & "OFF". temperature differentials. Adjust if necessary.					x	Certain controllers give direct electronic or digital readouts; others will require the placement of sensors in temperature baths to fully verify set points
Other Instruments	Check elapsed time meter, thermometer and flow indicator for proper operation.			x			

MAINTENANCE SCHEDULE - DRAIN-BACK PACKAGED DHW SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
CONTROLS AND MONITORING INSTRUMENTATION (cont'd)							
Wiring (Power)	Check insulation near controllers, contactors & motors for signs of shrinking or brittleness. Inspect for physical damage of wire or conduit					x	Overheating of wire may be due to poor relay contacts, loose terminals or overloaded pump motor; check.
Wiring (Sensors)	Verify that junctions, protective conduits and shielding are intact. Loosen off and retighten terminal screws.					x	

OPERATIONAL PROBLEMS CHART

Comprehensive "Automatic Monitoring" is not considered viable for small domestic hot water packaged heating systems. The capital cost for the required instrumentation and installation would be greatly out of proportion with the capital costs for the packaged solar systems.

Regular ongoing operational monitoring on the basis of "Routine Inspection", however, is considered necessary to achieve efficient operation and to detect, as early as possible, any developing faults which otherwise could lead to serious breakdowns and material damage.

OPERATIONAL PROBLEMS

DRAIN-BACK SYSTEMS

SOURCE OF PROBLEM	POSSIBLE CAUSES	CONSEQUENCES	PROTECTION	
			AUTOMATIC MONITORING	ROUTINE INSPECTION
PUMP: Failure to operate when required to.	- Power off - Blown fuse or tripped breaker - Electrical problems - Motor burned out - Impeller seized, blocked or disconnected. - Shut down on freeze stat. - Problems with sensors or controller - Open cct.in collector sensor wiring - Short cct.in storage tank sensor wiring	- No collection of solar energy	- Flow switch & alarm wired through photoelectric element and high limit t'stat.	- Observation of flow - Elapsed time indication - Thermometer
PUMP: Operating when not required to:	- Problem with sensors and/or controller - Faulty Switch - Faulty Wiring - Short cct.in collector sensor wiring - Open cct.in storage tank sensor wiring	- Reverse heat exchange - Potential frost damage	- Reverse heat exchanger alarm - Freeze protection and alarm	- Elapsed run time indication - Freeze prot. - Observation of flow
NO CIRCULATION: Pump Running	- Insufficient liquid in drain-back tank - Leak in piping system (fluid lost) - Part of piping system frozen up - Blockage in piping system - Strainer dirty - Insufficient pump head - Impeller or drive defective.	- No collection of solar energy - Pump overheating	- Flow switch alarm	- Observation of flow - Thermometer - Observation of liquid level in drain-back tank
CONTROLLER: Not operating correctly	- Not adjusted correctly - Sensors loose - Faulty wiring-short or open circuit - Faulty switches - Faulty electronics	- Inefficiency - Frost Damage	- Flow switch alarm - Freeze protection - Lo-Hi limit alarms	- Flow Indic. - Elapsed run time indication - Thermometer - Freeze protection

SOURCE OF PROBLEM	POSSIBLE CAUSES	CONSEQUENCES	PROTECTION	
			AUTOMATIC MONITORING	ROUTINE INSPECTION
LEAK IN PIPING SYSTEM	- Incorrect solder joint - Expansion/contraction causing break - Frost damage - Corrosion	- Loss of transfer fluid - No collection of solar energy - Poor or no water circulation - Pump overheating	- Low Liquid Level alarm - Flow switch alarm	- Visual Inspection - Observation of flow - Thermometer
FROST DAMAGE	- System operation out of control - Sensor(s) have come loose - Controller defective - Electrical fault-short or open circuit - Piping sloped incorrectly not all water drained out of collector and/or high level pipes. - Incorrect venting	- No flow - Freeze-up of collectors and drain-back loop pipes - Water damage	- Low Temp. Alarm and automatic pump cut-off	- Automatic pump cutoff
TEMPERATURE/PRESSURE RELIEF VALVE Keeps popping	- Defective relief valve - Over collection - Relief temp/press.set too low. - High limit set too high	- Loss of domestic water - Steam build-up	- High Temperature cutout to stop pump	- High Temperature cutout to stop pump - Thermometer
HEAT EXCHANGER	- Leak in heat exchanger - Pressure build-up due to closed shut-off valves	- Dom.water enters drain-back tank and overflows	- Pressure relief valve in heat exchanger circuit - High level alarm	- Press.relief valve. - Observation of liquid level in drain-back tank. - Observation of overflow through vent
LOW WATER LEVEL	- Normal evaporation - Leak	- No flow - Pump cavitating and overheating - No collection of solar energy	- Low water alarm - Flow switch	- Sight glass - Flow indication - Thermometer

OPERATOR'S GUIDELINES

1. POWER

- Power should always be on; check fuse or breakers.
- Controller set to "Automatic"

2. PUMP(S) AND FLOW INDICATOR(S)

- If pump(s) is/are on there should be flow. With "Petro Sun" system, both pumps must run simultaneously. If there is no flow make sure that:

  (a) Valves in drainback loop are open.
  (b) Valves in domestic water circuit are open.
  (c) Water level normal

3. ELAPSED TIME METER

- On a sunny day, the system should always have some run time. The number of hours that the system (pump) runs depends on:

  (a) How much domestic hot water is drawn
  (b) Hours of sunshine
  (c) Time of year
  (d) Outside temperature

  The system may also run (cycle) on cloudy days or at night provided that the domestic water temperature entering the solar tank is much colder than the outdoor ambient temperature. Such run time, however, should be minimal. If the elapsed time meter shows excessive running (eg: more than 10 hours on a sunny day), a control problem may exist. Check if temperature sensors have come loose at collector or at storage tank.

- If elapsed time meter shows no operation during sunny periods, check whether:

  (a) Temperature sensors have come loose or detached at collector or storage tank.
  (b) Freeze thermostat setting is correct.
  (c) Pump starts by resetting freeze 'stat. If so, manually stop system operation and advise technical staff.

4. TEMPERATURE - DRAIN-BACK LOOP

- Normally this temperature will vary between 6°C and 80°C depending upon:

  (a) How much domestic water is drawn
  (b) Hours of sunshine for day
  (c) Time of year
  (d) Outdoor temperature

  If temperature exceeds 80°C there may have been no domestic hot water drawn for extended periods. The drain-back loop pump will cycle off by the action of the high limit control which is normally set between 80°C and 90°C.

  If the temperature/pressure relief valve pops too often, the temperature set point of the high limit should be reduced.

- Consistent low temperatures on sunny days:
  (a) Check whether pump operates (elapsed time meter)
  (b) Check whether there is flow when pump operates.
  (c) Check whether controller set point is at automatic
  (d) Check run time.
  (e) Check whether part of collector bank is airlocked.
  (f) Pump not operating because of freeze 'stat lock-out. Follow procedure of paragraph 3(c).

  Note: Low temperature in drain-back loop may also reflect high domestic water draw; no action required.

5. LIQUID LEVEL IN DRAIN-BACK TANK

- Check liquid level regularly and add water through fill valve to make up for evaporative losses.
- If level drops sufficiently in a short period of time there may be a leak in the drain-back loop.
- If water continually overflows, a leak may exist in the heat exchanger and domestic water enters the drain-back tank.

Action:

Close gate valves in domestic water circuit to isolate heat exchanger. Open bypass valve and use auxiliary tank-heater for domestic water heating until repairs to heat exchanger are completed.

6. FREEZE PROTECTION THERMOSTAT

- This instrument should be set at 5°C; it protects the drain-back loop and the collectors from frost damage by stopping the pump. The freeze protection thermostat has a "manual reset" feature.

If it is found that the system has been shut down through the freeze protection thermostat, the technical staff should be advised and the system should be manually shut down.

7. Recommended Instrumentation Specifications

1. Pressure Gauge Tapping

Copper pipe stub with pet cock 6mm N.P.T.

Contractor's Cost: $5.00

2. Thermometer

Equivalent to "Weksler" 1TO4C; Range 0°C to 100°C, 50mm diameter face, 3.5mm stem diameter, 100mm stem length, all stainless steel construction, bi-metal type.

Contractor's Cost: $25.00

3. Flow Indicator

Suitable for operating conditions of 100°C and 150 kPa, NPT 12.5.

"DRY-CON" Inc., 840 Halpern Ave., Dorval, Que, Dome Spinner type.

"TACO" Flow Setter, 3090 Lenworth Dr., Mississauga, Ont. In-line flow meter complete with balancing valve.

"CALQFLOW" CF-450, orifice gravity type. Blue White Industries, Westminster, California.

"HEDLAND" EZ-View in-line flow meter, orifice/spring type. Brian Engineering Ltd., Kitchener, Ont.

Note: Certain flow indicators require modifications to ensure that they do not act as check valves.

Contractor's Cost: $50.00

4. Elapsed Time Meter

Electro-mechanical, 110 volt, AC synchronous motordriven counter with non-resettable, 6-digit hour and tenths of hour indication, CSA approved.
Equal to Bach Simpson #1357 ETIF.

Contractor's Cost: $50.00

5. Freeze Protection Thermostat

Equal to "Penn" series A19, single-pole, single-throw, 110V, to break on temperature fall, range adjustable from -15°C to 40°C with manual reset button. Unit complete with bulb well and packing nut assembly, 12.5mm NPT adapter and 110mm long stem.

Contractor's Cost: $65.00

7. Recommended Instrumentation Specifications - cont'd

6. Peterson Plugs

Brass construction, 6.25mm NPT with 110-Nordel seal complete with brass cap and seal.

- Ontario Mechanical Sales, Downsview, Ont.
- R.C. Wall and Co., London, Ont.

Contractor's Cost (each): $9.00

7. Water Level Indication

As standard equipment, a sight glass in the form of a clear plastic pipe is provided by the solar system package manufacturers. In certain systems the flow measurement device may also act as the water level indicator (pump-off).

8. Instrumentation - Installed Costs - (based on 1983 rates)

1. For One Pump Package

One	Pressure Gauge Tapping:	$ 5.00	
One	Thermometer:	$ 25.00	
	Brass fittings and gate valves:	$ 13.00	
One	Flow Indicator:	$ 50.00	
One	Elapsed Time Meter:	$ 50.00	
	Wiring:	$ 5.00	
One	Freeze Protection Thermostat:	$ 65.00	
	Copper Fittings:	$ 6.50	
	Wiring:	$ 5.00	
Four	Peterson Plugs:	$ 36.00	
	Total Material:	$260.50	$260.50
Labour:	Plumbing - 1.5 hrs.@ $25.00:	$ 37.50	
	Electrical-2.0 hrs.@ $25.00:	$ 50.00	
	Total Labour:	$ 87.50	$ 87.50
	Total Material and Labour:		$348.00
	Plus 10% Overhead:		$ 34.80
			$382.80
	Plus 10% Profit:		$ 38.28
	TOTAL INSTALLED COST:		$421.08

8. Instrumentation - Installed Costs - cont'd

2. For Two Pump Packages

Materials as for One Pump Package:	$260.50	
plus:		
One Flow Indicator:	$ 50.00	
Total Material:	$310.50	$310.50
Labour: as for One Pump Package:	$ 87.50	
plus:		
½ hr. for plumbing @ $25.00:	$ 12.50	
Total Labour:	$100.00	$100.00
Total Material and Labour:		$410.50
plus 10% overhead:		$ 41.05
		$451.55
plus 10% Profit:		$ 45.16
TOTAL INSTALLED COST:		$496.71

3. Special Note

The cost estimates provided in the preceeding two sections reflect the expenditures which would be required to completely retrofit already-installed solar DHW package systems with the recommended operational monitoring instrumentation.

These costs could be reduced considerably by a number of factors:

(a) Most typical solar DHW package systems come complete with certain basic monitoring equipment -- this often includes 1-2 thermometers and pressure gauges and, in certain cases, a sight-flow indicator.

(b) Part of the cost for the recommended monitoring instrumentation involves the installation labour; for solar systems not yet in place this component could be made much smaller.

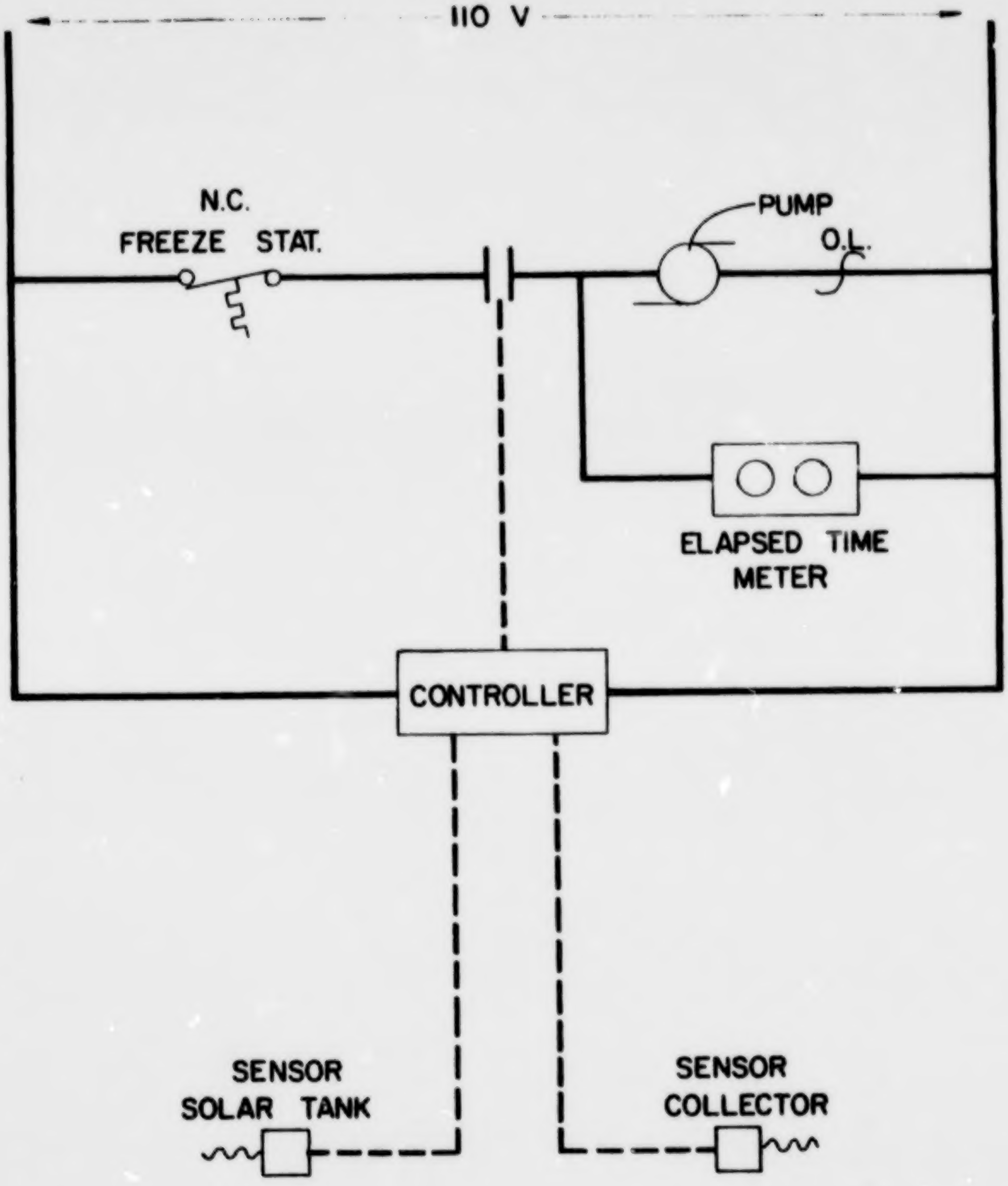
Plumbing: Time required during original installation of the valves, Peterson plugs and fittings is minimal.

8. Instrumentation - Installed Costs - cont'd

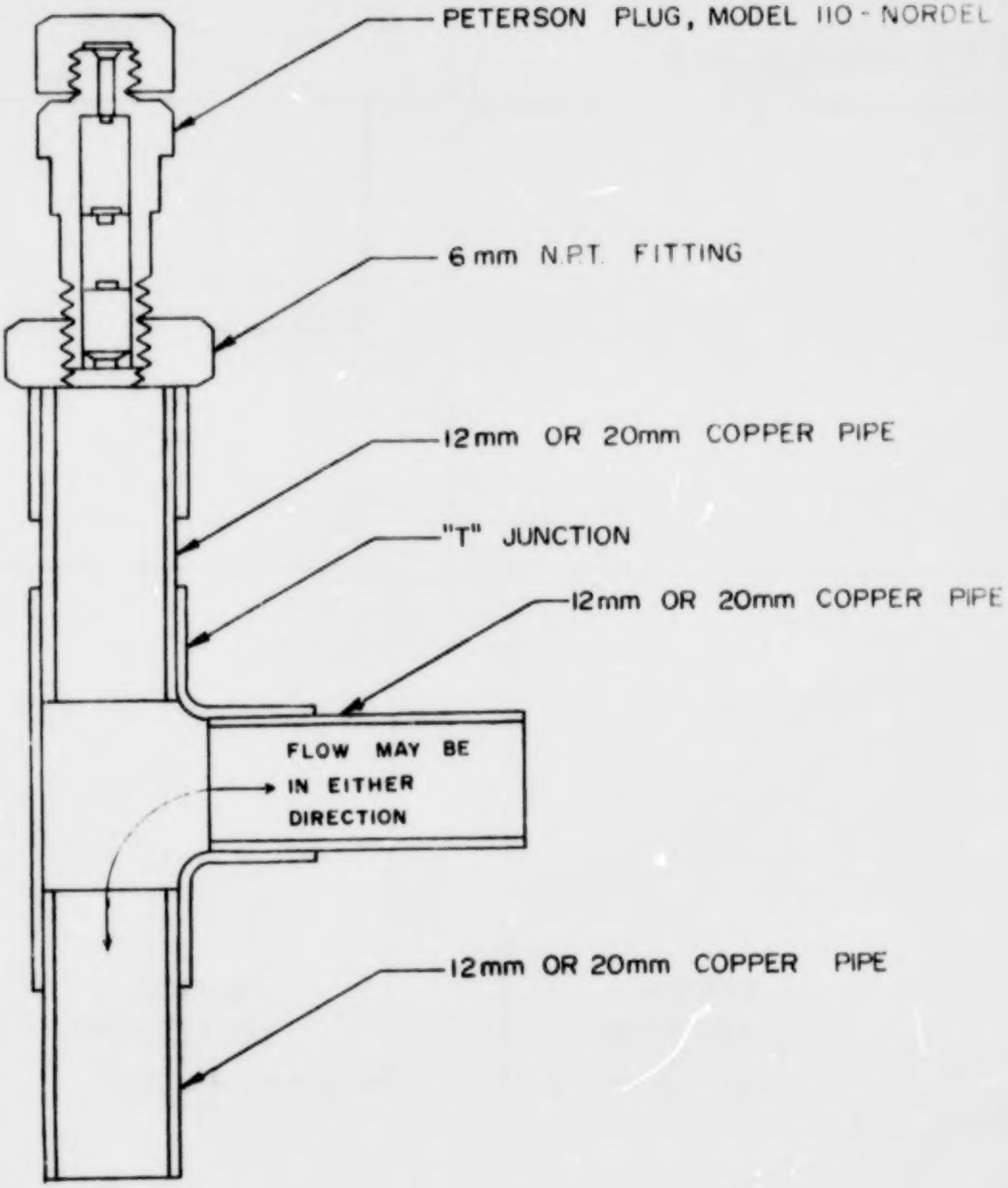
3. Special Note - cont'd

Electrical: If specified in the original order, certain simple modifications could be made by the manufacturers of the package systems to provide an elapsed-time meter and separate freeze protection unit within the main control panel. Another option would be the provision of plug-in outlets attached to the pump motor and power control circuits.

OEM: Prices used herein are quoted from local supply houses. Manufacturers will buy in quantity at OEM discounts at substantial cost reductions.



ELECTRICAL WIRING DIAGRAM



INSTALLATION DETAIL PETERSON PLUG

OPERATIONAL MONITORING AND MAINTENANCE

PHASE II - SOLAR ASSISTED DOMESTIC HOT WATER HEATING SYSTEMS

MEDIUM TO LARGE CAPACITY CLOSED LOOP SYSTEMS

REVISED MARCH 1984

OPERATIONAL MONITORING AND MAINTENANCE

PHASE II - SOLAR ASSISTED DOMESTIC HOT WATER HEATING SYSTEMS

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INTRODUCTION

The general concept of Operational Monitoring and Maintenance is to provide methods of ensuring:

- that the solar heating system is operating as designed.
- that operational problems and system breakdowns are detected as early as possible.
- that action is taken before serious damage and expensive repairs are incurred.
- that a long life expectancy of the system can be realized.
- that long-term operation and maintenance costs are kept to a minimum.
- that maintenance is performed on a regular, scheduled basis.

MONITORING STRATEGY

The methodology by which monitoring is accomplished for the engineered domestic water solar heating systems should take into account:

- that solar system instrumentation of sufficient accuracy and dependability is provided, to facilitate performance monitoring suitable for start-up, fine tuning, routine inspection, performance verification and trouble shooting.
- that a visual or audible alarm is provided to annunciate upon abnormal conditions.
- that operational check lists and maintenance schedules become part of a regular maintenance program.
- that energy monitoring can be integrated without unnecessary duplication of monitoring hardware.

OPERATIONAL MONITORING AND MAINTENANCE

PHASE II - SOLAR ASSISTED DOMESTIC HOT WATER HEATING SYSTEMS

MEDIUM-TO-LARGE CAPACITY CLOSED LOOP SYSTEMS

1. Description of Systems:

Systems in this category may include installations with a minimum of 60 collectors. These systems normally would be custom designed and may vary to a degree in concept depending on the application and the preferred design procedures. Except for these variations, the design and operation of the closed loop systems can be described as follows:

The closed loop concept employs a primary/secondary heating system. The primary circuit consists of a pressurized loop containing, as the heat transfer liquid, an anti-freeze solution which is circulated through the solar collectors and a heat exchanger. The secondary circuit is represented by the domestic water to which the heat contained in the primary circuit is transferred.

The two heat transfer methods most commonly used are:

1. Shell and tube or plate type converter with pumped primary and secondary circuits.
2. Tube bundle insertion into storage tank without secondary circuit pump.

Local environmental and health codes may require these heat exchangers to be double wall construction, to prevent cross-contamination between the anti-freeze and the domestic water.

1. Description of Systems - cont'd

The anti-freeze contained in the primary circuit is circulated by one or more pumps whenever heat is available at a temperature suitable to provide domestic water heating. Circulation is initiated by a controller which senses fluid temperature at the collectors and in the solar storage tank.

Several methods are used to control the flow of antifreeze through the primary circuit:

1. Single pump on-off control which is activated and deactivated upon fixed temperature differentials.
2. Multiple pumps, or multi-speed pumps, which are activated and deactivated in sequence upon staged temperature differentials.
3. Variable flow through closed loop, achieved through speed control of pump motor or through control valves in the form of automatic throttling, diverting or mixing; generally controlled to maintain a fixed anti-freeze temperature differential through the collectors.

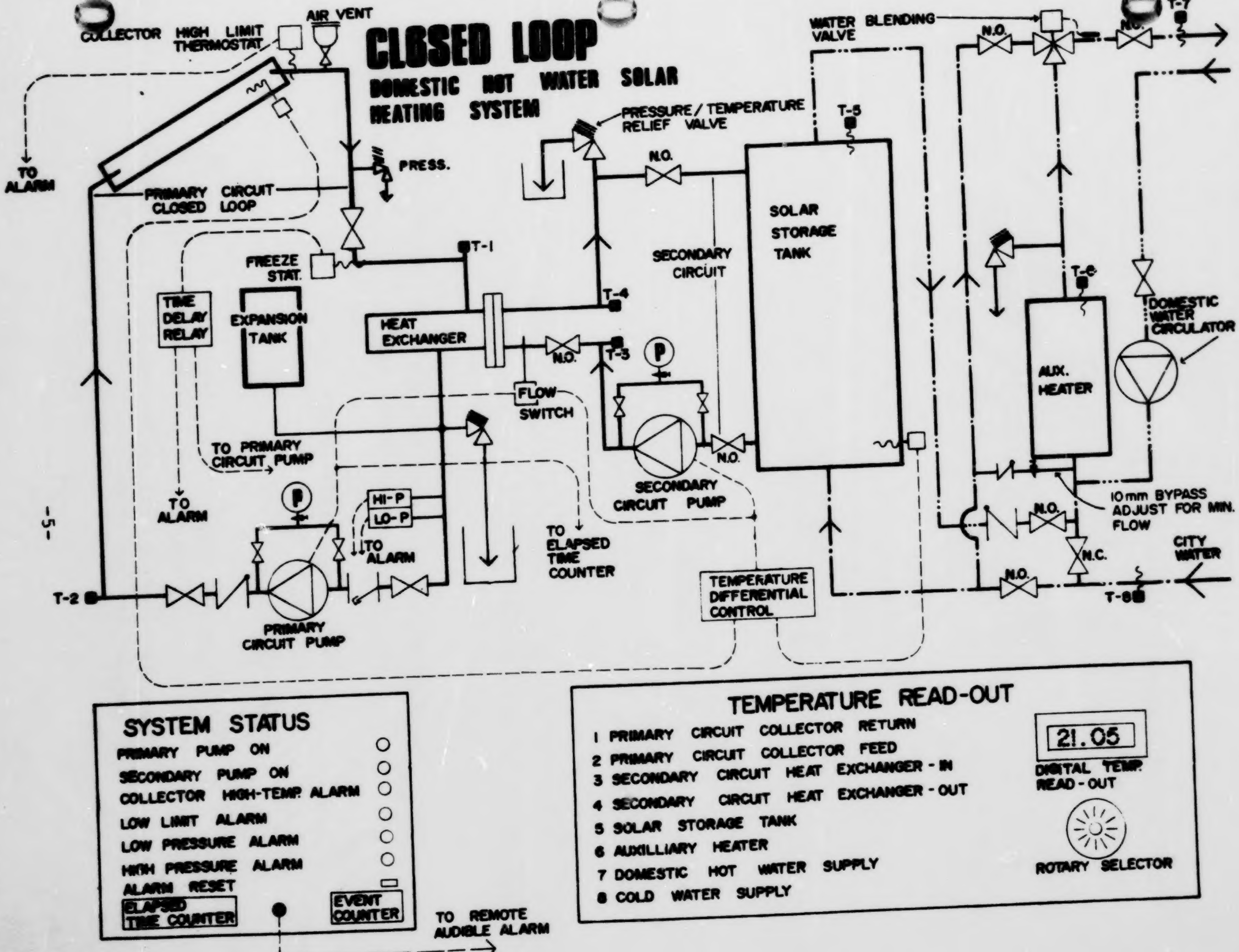
The solar storage tank contains domestic water, preheated by the solar system, at temperatures which vary according to the amount of solar energy absorbed by the collectors and delivered, and the rate of domestic water consumption.

Auxiliary domestic water heating normally is provided in separate storage tank-heaters installed in series, downstream of the "solar storage Tank".

Solar System Diagram

The following diagram, entitled "CLOSED LOOP DOMESTIC HOT WATER SOLAR SYSTEM" indicates instrumentation necessary for operational monitoring. The circuit diagram shown reflects the most commonly engineered closed loop system. Certain instrumentation modifications may be required for other types of circuits.

CLOSED LOOP
DOMESTIC HOT WATER SOLAR HEATING SYSTEM



2. Instrumentation Guideline

1. Temperature Indicators:

Temperature indicators are necessary for routine checks and to afford detection of abnormal operating conditions:

Experience has shown that commercially available bimetallic or liquid-filled thermometers are of little use to the solar system operator. Such thermometers are usually out of calibration to a point where a comparison of fluid temperatures becomes meaningless.

Both the primary and secondary circuits have wide ranges in operating temperatures, eg: 5°C to 90°C. The relative temperatures, or temperature differentials, between circuit supplies and returns and the approach temperatures between primary and secondary circuits, however, are very small in closed loop solar heating systems:

- During maximum insolation, the temperature difference between collector feed and return is usually 5°C to 8°C.

- The average difference on a sunny day between collector feed and return is 2.5°C to 4°C.

- The temperature differential between secondary circuit supply and return fluctuates between 0°C and 10°C.

and

- The approach temperature between primary circuit (collector loop) return and secondary circuit supply (leaving heat exchanger) usually fluctuates between 0°C and 10°C.

2. Instrumentation Guideline - cont'd

1. Temperature Indicators - cont'd

In addition to knowing the temperature levels of the primary/secondary circuits, it is the knowledge of the foregoing temperature differentials which indicates to the operator whether or not the solar heating system is operating correctly. Because the temperature differentials within the primary and secondary loops are small (0-10°C) but may occur anywhere within the system operating range of 5-95°C, temperature sensors of exceptional accuracy and linearity are required to permit meaningful measurements. For a typical operating temperature differential of 5°C, two measurements of plus or minus 0.5°C accuracy will produce a reading within 1°C, or 20% of the actual value. For the purpose of performance monitoring, this accuracy is considered a minimum standard.

Principle Types of Temperature Sensors

(a) Liquid-Filled:

There are many types of liquid-filled temperature indicators and sensors, the most common of which are mercury or coloured-alcohol glass stem thermometers. The principle by which these operate is the expansion of liquid volume that occurs with increasing temperature. By using a large bulb and a small capillary the effect is magnified to give a direct visual reading along a linear scale. Typical accuracy of glass stem thermometers is plus or minus 2°C and may depend upon immersion depth and ambient temperature. Because of these restrictions, liquid-filled thermometers have little application in solar system performance monitoring other than as general indicators.

2. Instrumentation Guideline - cont'd

1. Temperature Indicators - cont'd

(a) Liquid-Filled - cont'd

If a single thermometer is used to access several measuring points, the comparative readings will be more meaningful than if separate, unmatched, or uncalibrated thermometers are used.

(b) Mechanical (Dial)

Widely used in commercial applications because of their durability and portability, most mechanicl thermometers function by using the different expansion co-efficients of dissimilar metals to bend or distort a bimetallic element. In their simplest form two metals with very different expansion properties are bonded together, fixed at one end, and attached to an indicator needle at the other. Bimetallic thermometers generally have a rapid response time and an easily readable dial but typical accuracies of plus or minus 2°C and the non-repeatability of readings due to linkage backlash and bimetal aging limit their usefulness in solar system monitoring. As with the liquid-filled type, it is better to use a single mechanical thermometer for comparative readings than to rely upon the measurements from separate units.

(c) Thermocouple

Thermocouple sensors are employed in many types of temperature measurement systems; they are available in a wide variety of physical forms, are durable and inexpensive, and often permit a wide temperature range.

2. Instrumentation Guideline - cont'd

1. Temperature Indicators - cont'd

(c) Thermocouple - cont'd

Thermocouple sensors measure the changes in voltage produced by the heating of the junction of dissimilar metals or alloys. This voltage increases with temperature but in a very non-linear fashion. The voltage changes are extremely small -- in the order of tenths of a millivolt per degree centigrade. Thus, special electronic instrumentation and stable references are required to obtain usable temperature indication from thermocouple sensors.

In addition, special wiring procedures must be used when attaching remote sensors in order to ensure that unintentional junctions and voltages are not introduced into the system. While properly constructed thermocouple systems may achieve an accuracy of plus or minus 1°C or better, their extremely small signal, their lack of stability, and their requirements for critical wiring procedures make them more suitable for wide-temperature-range industrial applications than for solar hot water systems.

(d) Thermistor

Thermistor sensors find wide application in temperature measurement and control systems because of their speed, their relatively high output, their availability and their low price. All thermistors are composition resistors whose resistance decreases with increasing temperature.

2. Instrumentation Guideline - cont'd

1. Temperature Indicators - cont'd

(d) Thermistor - cont'd

This phenomenon is non-linear, (often exponential), requiring that each sensor type be matched with a specifically adapted readout/control device. The sensors require some power to operate and self-heating can be a problem.

In solar domestic hot water control systems, 2-wire thermistor sensors have performed adequately. For accurate temperature measurement (plus or minus 1°C), lead-length and lead-temperature compensation features must be incorporated by means of 3 or 4 wire leads to each sensor point.

Largely because of the non-standard manufacturer-specific nature of thermistor sensors, their use in multiple-point performance monitoring of solar systems is not recommended.

(e) Semi-conductor

A recent introduction to the temperature measurement field, the "IC" (integrated-circuit) sensors, such as the LM-334, rapidly are becoming accepted in a number of control and monitoring applications. While the detailed internal operations of such devices are quite complex, most are designed to produce a voltage or current which increases with sensor temperature, with low sensitivity to supply voltages, lead-lengths etc.

2. **Instrumentation Guideline** - cont'd

1. **Temperature Indicators** - cont'd

(e) **Semi-conductor** - cont'd

Several manufacturers have settled upon a standardized output that produces approximately 10 mV per degree Kelvin; thus at 0°C (273.16°K) the output is 2.732V and at 100°C (373.16°K) the output is 3.732V. The devices have good linearity, give a high output and are quite inexpensive.

Semi-conductor sensors require a power supply, are self-heating, and have relatively slow response. Typical installed accuracies are plus or minus 1°C.

At present, IC sensor instruments are not recommended for monitoring the temperature of solar domestic hot water systems because no independent standard exists for their calibration, accuracy and stability. It is likely that this situation will change in the future and that IC sensors will become much more widely used.

(f) **RTD Platinum**

Accepted for many years as the "standard" temperature sensor, RTD Platinum (Resistance Temperature Detection) devices display an increasing resistance with increasing temperature. This is a property shown by most pure metals; platinum is chosen because of its exceptional long-term stability and its tolerance to high temperatures.

2. Instrumentation Guideline - cont'd

1. Temperature Indicators - cont'd

Of the five main types of temperature sensors (liquid filled, bimetallic, thermocouple, resistance temperature detectors [RTD's], and semiconductor), the RTD devices (particularly platinum RTD's) possess the best combination of initial accuracy, linearity, stability and industry standardization.

The use of standardized resistance element values and calibrations is of great advantage in permitting the interchanging of sensors and measurement instrumentation. At present, the DIN 43760 standard "alpha=0.0385/ohm/°C" is most commonly used. Using "off-the-shelf" RTD elements, wiring, switches and digital indicators, the target of overall system accuracy of plus or minus 0.5°C is readily attainable.

Caution must be observed during the selection and installation of such equipment so that lead-length and lead-temperature variations are compensated for (usually by 3 or 4 wire sensors) and that junctions and wiring are performed to the manufacturer's specifications.

For temperature measurements of a less critical nature (such as solar storage tank or supply cold water) the same measurement electronics can be used with lower precision (and less costly) RTD sensors.

2. Instrumentation Guideline - cont'd

1. Temperature Indicators - cont'd

It is recommended that all temperature sensors be installed in stainless steel thermometer wells located at piping tees in the solar system circuits. This would allow service, replacement and calibration procedures to be accomplished without loss of system fluid. Sensors should be installed in the wells with silicone thermal conductive compound to ensure accurate readings.

2. Provisions Made for Collector Bank Water Balancing

Provisions should be made at each individual collector bank to allow measurement of the collector return temperature. During system commissioning, this will facilitate water balancing in an effort to achieve uniform flow through the collectors. The balancing would be performed on a sunny day with the system operating. Ideally, once balanced, each collector bank should indicate the same temperature differential between feed and return. During operation, periodic checks should be made to verify that equal flow exists.

A temperature imbalance would also point to a potential collector bank air lock; a situation which can occur after a system has stagnated.

It is recommended, therefore, that thermal wells be installed at the outlet of each collector bank, suitable for the insertion of a portable electronic probe.

2. Instrumentation Guideline - cont'd

3. High Temperature Alarm

Without fluid circulation during periods of insolation, the collector will stagnate. The fluid in the collectors may reach temperatures above 100°C and the transformation of the fluid to a vapour becomes possible. Consequently, the system pressure may increase and some fluid may be discharged through the relief valve. A stagnated collector is also subject to increased thermal expansion and potential leaks.

On a system with automatic air vents, anti-freeze may be lost in the form of vapour. It is recommended that a temperature sensor be installed in the pipe as close as possible to the outlet of a designated collector to provide an alarm signal whenever temperatures in excess of 95°C are measured.

4. Pressure Gauges:

(a) Primary Circuit Pump - (Closed Loop)

A pressure gauge through switchover valves should be installed across the primary circuit pump, capable of measuring pump suction or discharge pressure as follows:

1. When the pump is off the gauge will read system static pressure.

2. During pump operation, (provided that the expansion tank is connected near the suction side of the pump), the gauge will read pump head plus system static pressure.

2. Instrumentation Guideline - cont'd

4. Pressure Gauges:- cont'd

(a) Primary Circuit Pump - (Closed Loop) - cont'd

3. The difference between the two readings will be the pressure of the pump head.
4. The gauge can be used also to check whether flow exists in the primary loop by manually closing off any one valve installed in the primary loop while the pump is running. Once the valve is shut, the discharge pressure should rise slightly. The resulting pressure will indicate system static pressure plus pump "shut-off head". This test, however, should not be performed on a routine basis; rather it may be performed as a means of trouble-shooting. In order to avoid pump overheating, the valve in the circuit should not be left closed for any length of time.

The pressure gauge is also useful to initially charge and pressurize the primary circuit. The "fill pressure" or safe minimum operating pressure, is calculated by the system design Engineer and varies among installations. As the temperature of the fluid in the closed loop increases, the system pressure increases.

A relationship of consistency will exist between the closed loop fluid temperature and the system pressure. This relationship should be determined and recorded for comparison purposes during the commissioning of the installation. This relationship is more pronounced on large volume systems of higher buildings.

2. Instrumentation Guideline - cont'd

4. Pressure Gauges: - cont'd

(a) Primary Circuit Pump - (Closed Loop) - cont'd

If this relationship changes, there has been a change in the quantity of fluid contained in the closed loop. Fluid may have been lost through:

- the pressure relief valve
- the air vent
- the pump seals
- a leak in the piping system
- a leak in the heat exchanger
- defective expansion tank (water logged).

If an unusually low pressure exists, (below established fill pressure), the system may not be pressurized relative to atmosphere at the top of the loop; a vacuum may exist and air entrainment is possible. In this case, fluid must be added and the system purged free of air.

If an unusually high pressure exists and the relief valve has discharged fluid, the reasons could be:

- fill pressure originally set too high
- pump not operating - collectors overheating with possible steam build-up; stagnation conditions.
- no flow condition in closed loop
- expansion tank defective - water logged
- expansion tank too small for system
- system temperature unusually high, over-collection of solar heat - possible steam formation in collectors

2. Instrumentation Guideline - cont'd

4. Pressure Gauges: - cont'd

(b) Heat Exchanger:

The provision of pressure gauges to measure the primary circuit fluid pressure drop across the heat exchanger is considered optional.

Pressure gauges may be used to detect a change in differential pressure due to heat exchanger fouling or blockage. An increased pressure drop through the heat exchanger, however, would automatically reduce the flow through the primary loop and this, alternatively, could be detected by an increase in the operating temperature differential between collector feed and return lines.

(c) Secondary Circuit Pump

A pressure gauge with switch-over valves should be installed to facilitate indication of suction and/or discharge pressure.

5. High-Low Pressure Alarm

In order for the closed loop (primary circuit) to operate correctly, the system pressure must stay within prescribed limits.

It is recommended that a pressure sensor with high and low contacts be provided and wired to the status panel for alarm annunciation.

2. Instrumentation Guideline - cont'd

6. Elapsed Time Indicator - Primary Circuit Pump

The provision of an elapsed time meter showing accumulated run time of the primary circuit pump will give the operator reasonable indication of the solar system performance.

Control system problems, and especially abnormal continuous operation with resulting energy waste, may be detected by regular observation of run time.

7. Event Counter

The event counter is an electro-mechanical device indicating number of primary loop pump on-off cycles. This relatively inexpensive device would be very useful to set up initially the temperature differential settings activating and de-activating the circulating pumps. In addition, the event counter could be useful in detecting abnormal and erratic cycling due to intermittent wiring connections.

8. Freeze Protection

Regular monitoring of the physical and chemical properties of the heat transfer liquid is essential to guarantee frost protection of the primary circuit. Reference should be made to the "Packaged Closed Loop Systems" manual for information concerning the monitoring and maintenance of the anti-freeze solutions.

2. Instrumentation Guideline - cont'd

8. Freeze Protection - cont'd

Automatic frost protection must be considered for the secondary circuit because of the possibility of freeze-up under certain abnormal conditions:

(a) The secondary side of the heat exchanger can become subject to freeze-up if the primary circuit pump runs out of control.

(b) It is possible to freeze the secondary circuit upon start up and subsequent cycling of the primary pump where a large amount of antifreeze exists in pipes exposed on the roof.

If water always circulates through the secondary circuit when the primary circuit pump is in operation, however, the probability of freeze-up is reduced greatly.

Recommended Frost Protection Procedures

1. Primary circuit pump permitted to operate only if flow is proven to exist in the secondary circuit.
2. Freeze protection thermostat set at 5°C, installed in collector return line near heat exchanger, to shut down primary circuit pump.
3. Time delay relay set between 1 and 5 minutes to delay pump shut-down and alarm in order to prevent nuisance tripping upon start-up. Systems with large quantity of anti-freeze exposed to the outdoors (pipes on roof), will require longer time delay than systems with a limited amount of exposed piping.
4. A visual and audible alarm should annunciate the shut-down under "Freeze Conditions".

3. Operational Monitoring and Maintenance Procedures

The type and extent of instrumentation provided for operational monitoring is considered to be that necessary to furnish the operator with sufficient information to make routine diagnoses, to calibrate and adjust the controls, and to ensure annunciation of alarm conditions.

The "Operator's Check List" should be used to record operating conditions and to perform operational analyses. Certain modifications and amendments may be required to the check list in order to suit the actual system design concept. The frequency of use depends upon the complexity and performance record of the solar system.

The "Maintenance Schedule" separates the system into components and lists the recommended procedures and frequency of each maintenance task. This schedule may have to be expanded or altered in order to accommodate other design concepts or specific manufacturer's recommendations.

The Operational Problems Chart serves as an aid to system trouble-shooting.

The use of the "Operator's Check List" may help in the detection of operational problems. The "Operator's Guidelines" reflects system concepts illustrated in this manual and explains the operation of individual control and monitoring components. It will help the operator to properly control and monitor the system, to identify problems, and to perform the necessary corrective measures.

OPERATOR'S CHECK LIST

Medium-to-Large CLOSED LOOP SOLAR WATER HEATING SYSTEM

PROJECT: SYSTEM MANUFACTURER:

OPERATOR: MONTH: YEAR:

Date and Time	Weather (Check One)			Approx. Outdoor Temp. °C	Power On Yes or No	Pumps On		Temperatures (°C)								System Press. kPa	Elapsed Time Hours & Tenths of Hours	Interval Counter Total Counts	System Alarms				Overflow Containers (Wet/Dry)		Visible Leaks Yes or No
								Heat Exchangers				Storage Tanks		Water Supply					Coll. High Temp Yes or No	Low Limit Yes or NO	Pressure		Closed Loop	Solar Storage Tank	
								Primary		Secondary											High Yes or No	Low Yes or No			
	SUNNY	PARTLY SUNNY	CLOUDY NO SUN			Primary	Secondary	IN T-1	OUT T-2	IN T-3	OUT T-4	Solar T-5	Aux. T-6	Hot T-7	Cold T-8										

MAINTENANCE SCHEDULE - MEDIUM-TO-LARGE CLOSED LOOP SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
Complete System	Operational Checklist	x	x	x		x	Initially more frequently, then as required.
COLLECTORS:							
Panels	Inspect for leaks, breakage, overheating panels.		x				Sunny days (pump running). Panels with same exposure should operate at approximately the same temperature
	Examine absorber plates for signs of corrosion, flashing or discolouration.					x	
	Manage snow		x				Winter months only
Glazing	Wash externally with warm soapy water.					x	More often if necessary.
Vents	Check and clear vent holes.					x	Also if chronic condensation is observed.
Supports/Mounting and Fasteners	Check structure, tighten bolts, inspect isolation pads, touch-up where corrosion is evident					x	
Piping	Inspect hangers and supports. Adjust, check pipe slopes					x	Resupport pipes if sagging
	Check flow balancing for each collector array. Complete balancing procedures are outlined in the Solar Programs Office Commissioning and Monitoring Procedures Documents					x	Temperature at inlet/outlet of each array can be measured with calibrated electric thermometer near noon on a sunny day (with system running)

MAINTENANCE SCHEDULE - MEDIUM-TO-LARGE CLOSED LOOP SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
COLLECTORS: (cont'd)							
Piping (cont'd)	Verify pipe jackets and insulation. Repair weatherproof jackets where necessary. Replace wet fibreglass insulation. Inspect for UV degradation of plastic pipe jackets.					x	
	Check pipe connections, inter-panel hose couplings and roof penetrations.					x	Use 95-5 solder for copper pipe repairs
Control Modules	Verify wiring/connections and mounting of sensors				x		
EXPANSION TANK							
Diaphragm Type	Drain system. Check precharging. Replace with EPDM type if water-logged.					x	Usually 85kPa or as specified.
Tank Type	Check level. Recharge if required.			x			Also upon alarm signals. Normally tanks are sized to be 1/3 full when fluid is cool, 2/3 full when system is at maximum temperature.
Open Type	Check fluid level. Fill if necessary. If automatic, inspect and clean probes.				x		
PUMPS AND MOTOR CONTROLS							
Motors	Check amps, temperature, RPM					x	
Contactors and Switches	Inspect and torque connections. Check for pitting; replace points					x	
Bearings	Listen for vibration/noise. Lubricate				x		Where applicable

MAINTENANCE SCHEDULE - MEDIUM-TO-LARGE CLOSED LOOP SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
PUMPS AND MOTOR CONTROLS (cont'd)							
Seals	Check carbon/ceramic, O-ring and mechanical seals for noise, wear and leakage.			x			As per manufacturer's recommendations. Replace if leaking
Couplings	Inspect for play. Tighten if loose			x			
Mounting and Alignment	Verify. Adjust if required					x	
Impellers	Listen for noise. Measure developed pressure				x		
HEAT EXCHANGER	Measure & record pressure drop through convertor			x			
	Clean and inspect units as per manufacturer's recommendations. Service if pressure drop exceeds initial value by 20%.					x	Shell & Tube Exchangers: If floating heads, rod-through tubes. If bundle type use chemical cleaning & flushing. If plate type, disassemble and clean using fibre brush with soda ash/detergent solutions.
	Replace gaskets						As necessary.
STORAGE TANKS	Inspect tank insulation					x	
	Inspect linings for cracking, deformation or melting. Storage tank lining to be identified & labelled.					x	Repairs should be performed as per manufacturer's recommendations. Different tanks have significantly different maximum temperature limitations and repair & maintenance requirements.

MAINTENANCE SCHEDULE - MEDIUM-TO-LARGE CLOSED LOOP SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
STORAGE TANKS (cont'd)							
	Typical linings for tanks include directly applied cement (sometimes referred to as 'stone-lined'), cement applied to welded mesh, calcium aluminate coatings (eg: "Alcrete"), skin-tight copper linings, epoxy finishes and vinyl plastic sheet inserts.						All can benefit from frequent flushing and cleaning.
	Verify condition of magnesium anodes and other corrosion protection devices.					x	Where installed.
Cement Lined	Drain, open manhole, carefully inspect lining. Patch with material/method recommended by manufacturer. Remove debris, flush, replace gasket if necessary and refill.					x	During winter months, preferably on cloudy day. Provide adequate lighting and ventilation.
Glass Lined	Inspect. Repair/replace as per manufacturer's recommendations					x	Required only if blocked or if corrosion evident in water supply can be traced to tank.
Plastic (Vinyl or Epoxy)	Inspect for damage, leaks or discolouration. Drain, remove debris then flush. Repair as per manufacturer's recommendations.					x	Water should not penetrate behind these liners.
Probes & Sensors	Disconnect, clean and manually test if possible					x	Well-mounted units can be accessed externally.

MAINTENANCE SCHEDULE - MEDIUM-TO-LARGE CLOSED LOOP SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
PIPING ACCESSORIES							
Primary and Secondary Loops	Verify mounting, hangers and slopes. Check for leaks and damaged or wet insulation					x	Repair as required
Valves	Manually operate. Check for stem leaks etc. Inspect glands and seals. Verify that they are returned to balanced or normal (NO/NC) operating positions					x	Replace if necessary. Valves should have tags attached, stating their function & normal setting
Check Valves/ Vacuum Breakers	Open, clean and verify operation where possible. Check springs on spring-operated valves.					x	
Strainers	Open, remove basket, clean and flush			x		x	More frequently if indicated by excessive pressure drop, and during start-up
Water Filters	Monitor pressure drop.			x			Replace media/cartridge as required.
Relief Valves	Inspect if outlet port & discharge pipe are clear. Manually operate levered type. Verify setting if adjustable.					x	Replace overflow container under outlet pipe (if present).
Air Vents	Ensure floats and seals are clean on serviceable units. Check that vent caps are loosely screwed on. Inspect for leaks.				x		Should be isolated by shut-off valves after commissioning.

MAINTENANCE SCHEDULE - MEDIUM-TO-LARGE CLOSED LOOP SYSTEMS

COMPONENT	PROCEDURE	DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	COMMENTS
PIPING ACCESSORIES (cont'd)							
Fluids	Check pressure. If necessary top up with specified solar anti-freeze solution.				x		Chronic loss of liquid indicates system fault. Check for leaks in pipes, valves and air vents.
	Inspect for presence of colour or suspended solids.			x			
	Measure anti-freeze strength, pH and alkalinity. Conduct additional chemical tests and treatment as formulated for the particular solar system fluid.				x		Important before winter season. See Operator's Guidelines. Also check after hi-temp alarms or if collector stagnation is suspected.
CONTROLS AND MONITORING INSTRUMENTATION							
Differential Controller	Verify correct system status indications for "OFF", "MANUAL" & "AUTOMATIC" control positions. Check that pumps are actually running per control indications.			x			
	Turn power off, then reset to verify controller start-up operation.			x			Preferably on sunny day.
	Measure and adjust controller "ON" and "OFF" temperature differentials					x	Certain controllers give direct electronic or digital readouts; others will require the placement of sensors in temperature baths to fully verify set points

MAINTENANCE SCHEDULE - MEDIUM-TO-LARGE CLOSED LOOP SYSTEMS

		SCHEDULE					
COMPONENT	PROCEDURE	DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	COMMENTS
CONTROLS AND MONITORING INSTRUMENTATION (cont'd)							
System Status Panel	Operate and reset all alarm and status-indication circuits (high water, low water, high temperature, low temperature etc.)				x		
	Check elapsed time meter & event counter for proper operation.			x			
Temperature Readout Panel	Record temperatures at all sensing points and verify (T-collector out T-collector in etc.)		x				Pumps must be circulating for several minutes before readings are taken.
	Withdraw sensors from wells and check as-installed calibration at ice-point & boiling point of water					x	Required at least once during lifetime of a system & more often if system uses sensors other than platinum RTD units.
Wiring (Power)	Check insulation near controllers, contactors & motors for signs of shrinking or brittleness. Inspect for physical damage of wire or conduit					x	Overheating of wire may be due to poor relay contacts, loose terminals or overloaded pump motor; check.
Wiring (Sensors)	Verify that junctions, protective conduits and shielding are intact. Loosen off and retighten terminal screws.					x	

OPERATIONAL PROBLEMS

MEDIUM-TO-LARGE CLOSED LOOP SYSTEMS

SOURCE OF PROBLEM	POSSIBLE CAUSES	CONSEQUENCES	PERFORMANCE MONITORING
PUMP: Failure to operate when required to.	- Power off, Blown Fuse or Tripped Breaker - Not started through controller - Motor burned out - Impeller seized, blocked or disconnected. - Electrical Problem - Open cct.in collector sensor wiring - Short cct.in storage tank sensor wiring. - Control System Problems	- No collection of solar heat - Overheating of the transfer fluid - Steam build-up and loss of fluid - Stagnation Conditions: -Accelerated breakdown of antifreeze. -Corrosion -Frost damage	Collector High Temperature Alarm Observation of Elapsed Time Indicator Observation of Event Counter Observation of Temperatures
PUMP: Operating when not required to:	- Control set to Manual Oper - Problem with sensors and/or controller - Faulty Switch - Faulty Wiring - Closed cct.in collector sensor wiring - Open cct.in storage tank sensor wiring - Control System Problems	- Reverse heat exchange - Freeze-up of storage tank.	Low Temperature Alarm Frost Protection Thermostat to shut down pump Observation of Elapsed Time Indicator Observation of Event Counter Observation of Temperatures
EXPANSION TANK:	- Water-logged - Insufficient size - Originally charged too high -(Fill pressure too high) - Originally charged too low	- Build-up of pressure - Transfer fluid relieved - Air entrainment - Loss of circulation - Pump overheat - motor seized - Stagnation Conditions: - Breakdown of anti-freeze. - Corrosion - Frost damage	High Pressure Alarm Low Pressure Alarm Collector High Temperature Alarm Observation of Pressure Gauge

SOURCE OF PROBLEM	POSSIBLE CAUSES	CONSEQUENCES	PERFORMANCE MONITORING

CONTROLLER:
Not operating correctly
	- Not adjusted correctly
	- Sensors loose
	- Faulty wiring
	- Faulty electronics
	- Faulty switches
		- Inefficiency
		- Stagnation Conditions:
		  - Breakdown of anti-freeze.
		  - Corrosion
		- Frost Damage
			High Collector Temperature Alarm
			Low Temperature Alarm
			Observation of Elapsed Time Indicator
			Observation of Event Counter
			Observation of Temperatures

AIR VENT:	- Shut-off valves at automatic vents left open. - System originally charged too low	- Lack of circulation - Lack of heat collection - Pump overheating - Stagnation and Resultant Damage	High Collector Temperature Alarm Low Pressure Alarm Observation of temperatures Periodic verification of temperature rise through collector banks Observation of pressure gauges.
NO CIRCULATION Pump Running	- System air locked - Leak in piping system (fluid lost) - Part of piping system frozen up - Blockage in piping system - Impeller or drive defective	- No collection of solar heat - Stagnation and subsequent consequences (see above) - Pump overheating	High Collector Alarm Low Pressure Alarm Observation of Temperatures Observation of Pressure Gauges
LEAK IN PIPING SYSTEM	- Incorrect solder joints - Expansion/contraction causing break - Frost Damage - Corrosion	- Loss of system pressure - No collection of solar heat - Poor or no water circulation - Stagnation Conditions & subsequent consequences - Pump Overheating	Low Pressure Alarm High Temperature Alarm Observation of Pressure Gauges Observation of Temperatures
FROST DAMAGE TO PRIMARY CIRCUIT	- Transfer fluid lost its freeze protection ability	- No flow - Break in piping circuit - Loss of fluid	Regular check of quality of anti-freeze

SOURCE OF PROBLEM	POSSIBLE CAUSES	CONSEQUENCES	PERFORMANCE MONITORING
FROST DAMAGE TO SECONDARY CIRCUIT	- System operation out of control - Sensor(s) have come loose - Controller or sensor defective - Pump secondary circuit not running - Electrical fault	- Reverse heat exchange - Frost damage to secondary system tank and pipes - Flooding	Low Temperature Alarm Pumps interlocked such that primary pump can start only when secondary circuit pump is operating (flow switch).
RELIEF VALVE Keeps popping	- Fill pressure too high - Defective relief valve - Expansion tank water-logged - Expansion tank too small for system	- Loss of fluid - Air entrainment - Lack of fluid circulation - Stagnation Conditions and subsequent consequences	High Pressure Alarm Observation of anti-freeze discharged to overflow receiver Observation of Pressure Gauge
CROSS CONTAMINATION (for systems with direct heat exchanger)	- Leak in heat exchanger	- Loss of system pressure - Increase of System pressure	High Pressure Alarm * Low Pressure Alarm * Checking quality of anti-freeze Pressure testing primary circuit at least twice each year

* Partial Solution Only

OPERATOR'S GUIDELINES

1. SUNNY CONDITIONS AND PARTLY SUNNY CONDITIONS

The solar system should be cycling.

2. CLOUDY OR NO SUN CONDITIONS

The solar system may cycle only if the ambient outdoor temperature is sufficiently higher than the incoming water temperature or the temperature existing at the bottom of the solar storage tank.

3. POWER

If solar system does not perform as described under the above weather conditions, check main and branch circuit breakers.

4. PUMPS

1. Secondary Circuit Pump

Secondary circuit pump is activated and de-activated through differential temperature controller and should cycle as described under paragraphs 1 and 3. If NOT, check:

- Power connection, starter relay and wiring
- Differential controller setting
- Control sensor connections and transmission
- Controller

Note: If freeze thermostat has shut down the primary circuit pump, the secondary circuit pump should remain in operation as long as contact is made through the differential controller.

4. PUMPS - cont'd

2. Primary Circuit Pump

Except where stopped through the freeze 'stat, this pump should always run when the secondary circuit pump is operating.

If this is not the case, check:

- that all valves are open in secondary circuit
- flow switch and control wiring
- Primary circuit pump starter, relay power wiring and motor
- Secondary circuit flow through pressure gauge as described under paragraph 2.4. If no flow, check pump motor, coupler and impeller.
- Physical blockage in heat exchanger or pipes.

5. ELAPSED TIME METER

- On a sunny day, the system should always have some run time. The number of hours that the system (pump) runs depends on:

(a) How much domestic hot water is drawn
(b) Hours of sunshine
(c) Time of year
(d) Outside temperature

The system may also run (cycle) on cloudy days or at night provided that the domestic water temperature entering the solar tank is much colder than the outdoor ambient temperature. Such run time, however, should be minimal. If the elapsed time meter shows excessive running (eg: more than 10 hours on a sunny day), a control problem may exist. Check if temperature sensors have come loose at collector or at storage tank.

5. ELAPSED TIME METER - cont'd

- If elapsed time meter shows no operation during sunny periods, check whether:

  (a) Temperature sensors have come loose or detached at collector or storage tank.

  (b) Freeze temperature setting is incorrect.

  (c) System is off on "freeze".

6. EVENT COUNTER

This instrument is useful to detect excessive cycling of primary circuit pump or the absence of cycling.

Excessive cycling may indicate:

- Control system temperature differential settings too close.
- Control system problems
- Intermittent wiring connections

Absence of, or very infrequent cycling may indicate:

- Control system temperature differential settings too wide.
- Control system problems
- Open or shorted temperature sensors.

7. CIRCUIT TEMPERATURES

Refer to "Closed Loop" diagram on Page 5.

- T-1 temperature should always be higher than T-2.
- The temperature differential should not exceed 5-8°C at maximum insolation. If higher temperature differentials exist, and the loop operates at a reduced flow rate, check for:
    - partially closed valves
    - dirty strainer
    - pressure limits
    - blockage
    - air lock
    - pump problems
- During sunshine periods with pump operating, a small temperature differential should always exist. If this is not the case, check:
    - valves closed in collector loop
    - No-flow for any reason
    - snow covered collectors
    - system air locked
    - system operating outside of pressure limits
    - pump/impeller disengaged
    - freeze-up of collector loop

T-1 and T-2 temperature levels will fluctuate between 5°C and 95°C. Elevated temperature levels indicate large reserves of solar heated water. Without domestic water consumption, overcollection will result. This would lead to excessive loop temperature and pressure, and subsequent discharge of fluid through primary and/or secondary circuit relief valves.

7. CIRCUIT TEMPERATURES - cont'd

It is recommended that the system be set up such that the secondary circuit pressure/temperature relief valve pops before the primary circuit relief valve. This will safeguard against the loss of valuable anti-freeze.

While the secondary pump operates, T-4 temperature should always be higher than T-3 temperature. If this is not the case, there may be no-flow through the secondary circuit, the primary pump may be shut down on "Freeze" condition, or a control system problem may exist leading to reverse heat exchange.

T-4 temperature should always read lower than T-1 whenever the pumps are operating.

Temperatures 1, 2, 3, 8 and possibly 5, may read near room temperature during periods when no flow exists through these circuits.

T-5 will read the temperature of the stored water. This temperature usually varies between 5°C (high domestic water draw without solar energy collection) and approximately 80°C (little or no domestic water drawn in combination with maximum solar energy collection).

T-6 will read the temperature of the domestic water in the auxiliary heating tank; normally set between 50°C and 60°C.

T-7 is the domestic hot water supply temperature, normally maintained between 45°C and 70°C.

T-8 reads incoming cold water temperature.

8. CALIBRATION OF SENSORS

Calibration of all temperature sensors in their "as-installed" configuration can permit a system operator to monitor and maintain a solar domestic hot water circuit with significantly increased efficiency, accuracy and confidence. A simple calibration procedure using readily available materials may be performed at the ice-point of water (0.0°C) and at the boiling point of water (100°C), depending upon the atmospheric pressure:

> Crushed or broken ice is placed in a wide-mouth thermos containing cold water and the mixture is allowed to equilibrate. As long as significant quantities of both ice and water are present, the temperature of this mixture rapidly reaches 0.0°C (plus or minus 0.1°C) and is little affected by the local temperature or atmospheric pressure. One by one the temperature monitoring probes are withdrawn from their wells and placed in the thermos (near their original place of installation) and, after a settling period, the temperature is read at the central indicator unit.
>
> If 'zero' adjustment is possible, then each sensor channel is set to read 0.0°C while its corresponding probe is in the ice water bath; otherwise, a note of the observed error at 0°C (eg: T1 is 0.3° high, T2 is 0.5° low, etc) is made and clearly posted.

The same basic method is employed for the 100°C point except that water boiling vigorously on a hot plate is used and correction should be made for the atmospheric pressure.

8. CALIBRATION OF SENSORS - cont'd

The 'standard atmospheric' pressure is 101.3 kPa; the boiling point of water decreases approximately 0.3°C for each kPa reduction in pressure and increases 0.3°C for each kPa increase in pressure. At a local pressure of 100 KPa, therefore, water can be expected to boil around 99.6°C. The actual boiling point is thus determined and the sensor instrument error is adjusted or recorded as required.

9. SYSTEM PRESSURES

The pressure in the primary loop will fluctuate between the specified minimum fill pressure (system cold) and maximum operating pressure (system hot). Problems will result if the pressure is too low or too high:

> Too low a pressure will cause a vacuum at the elevated portions of the loop, resulting in possible air entrainment etc.
>
> Too high a pressure will result in overflow.

The hi-low pressure alarm will annunciate abnormal operating pressures.

Upon high pressure alarm:

- check whether alarm set point is correct
- check for collector stagnation or pump failure
- check for leak from domestic water circuit into closed loop through heat exchanger

9. SYSTEM PRESSURES - cont'd

Abnormally high pressure readings may also result from expansion tank system precharging problems, eg: air charge too high, collapsed diaphragm in original installation, or system originally charged too high (cold start).

Upon low pressure alarm:

- check whether alarm set point is correct
- check overflow container for loss of anti-freeze
- check for leaks in piping, collectors or heat exchanger
- check for expansion tank failure

The pressure gauge on the secondary pump will fluctuate with the city water pressure and is used to measure pump performance.

10. FREEZE PROTECTION THERMOSTAT

This instrument should be set at 5°C; it protects the secondary side of the heat exchanger from frost damage and stops the primary circuit pump through a time delay relay. The time delay relay is adjusted to prevent unnecessary cycling during start-up in very cold weather. During freeze alarm conditions, the secondary pump keeps running as long as the controller indicates useful solar collection.

The time delay may require adjustment to a longer period to account for cold fluid slugs which may occur in exposed parts of the primary loop.

OPERATOR'S GUIDELINES

11. COLLECTOR HIGH TEMPERATURE LIMIT THERMOSTAT

The collector high limit thermostat should be set to sound an alarm at temperatures in excess of 95°C; causes for which could be:

- Blown or tripped circuit breaker of pumps
- No-flow through collectors
- System air-locked
- System not pressurized at top of collectors
- Pumps not running
- Dirty strainer - blockage in piping system
- Control system problems

12. HEAT TRANSFER LIQUID

The primary circuit is usually charged with a propylene glycol/water solution with a corrosion inhibitor added.

The lower the temperature of the fluid in the loop and the lower the presence of oxygen, the better will be its physical and chemical stability. With elevated temperatures in the presence of free or dissolved oxygen, the oxidation process of the glycol solution is accelerated. This diminishes the effectiveness of the corrosion/oxidization inhibitor and decreases the strength (freeze protection) of the anti-freeze.

The duration of the frost protection and corrosion protection qualities of the solution varies from system to system.

Regular monitoring of the physical and chemical properties of the heat transfer liquid is essential to guarantee frost and corrosion protection. (Refer to "Packaged Closed Loop System" manual).

4. Recommended Instrumentation Specifications.

.1 Temperature Read-Out

1. Digital Temperature Readout for Panel Mounting:

Range:	0°C to 100°C
Resolution:	0.1°C minimum
Accuracy:	0.1% of scale plus or minus one digit, (max. 0.2°C) at 20°C
Stability:	100 ppm/°C
Type:	Standard Platinum RTD (DIN 43760), 3 or 4 wire lead-resistance compensated
Sampling Time:	1 second maximum
Display:	7 segment L.E.D. or illuminated L.C.D., 12 mm digits minimum.
Other:	Readout to be protected from damage caused by: - open RTD sensor line - shorted RTD sensor line - RTD short to AC line
Suppliers:	Omega Engineering Model 199 RTD Meter 1 Omega Drive, Stamford, Connecticut,USA Doric Model 410A, 3½ Digit Indicator Intertechnology, 1 Scarsdale Rd., Don Mills, Ontario. Enercorp Model PDAW-48 RTD Indicator P.O. Box 20, Station U, Toronto, Ont. Thermo Electric Analogic/ELS RTD Indicators, 12 Rutherford, South Brampton, Ont.

4. Recommended Instrumentation Specifications - cont'd

2. Rotary Selector Switch for Panel Mounting

Selector shall be a ten-position, low resistance, ($<0.01\ \Omega$) double or triple pole, make-before-break switch with screw-terminals, suitable for RTD measurements.

Suppliers:	Omega Engineering Model OSW3-10 Rotary silver-contact RTD switch, 1 Omega Drive, Stamford, Connecticut,USA
	Doric Model 409A, 10 Input, 3-pole Pushbutton switch. Intertechnology, 1 Scarsdale Rd., Don Mills, Ont.
	Enercorp 10-position, gold contact, Rotary switch, P.O. Box 20, Station U, Toronto, Ont.

3. Wiring:

Wiring shall be 3 or 4 wire (depending upon sensor), unshielded PVC-jacketed cable with #22 AWG stranded, tinned conductors (Belden 8443 or equivalent). Wiring shall be routed, without junctions, from control panel to position near sensor installation, then by flexible conduit to connection box affixed to thermowell. Connection to RTD sensor wires shall be made using a screw terminal block. Exposed wiring shall be run in metal conduit.

Suppliers:	Electro Sonic Inc., 1100 Gordon Baker Rd., Willowdale, Ont.
	Cesco Electronics Ltd., 4050 Jean Talon W., Montreal, Que.

4. Recommended Instrumentation Specifications - cont'd

4. Temperature Sensors:

Sensors shall be Platinum RTD (DIN 43760) type, wire-wound or thin-film elements mounted in a rigid, heat-conductive shell, maximum diameter 6.4mm.

Minimum Performance Specifications:

Plus or minus 0.3°C at 0°C
Plus or minus 0.6°C at 100C

Suppliers:

Omega Engineering Model PR-12,
Platinum-100 RTD
1 Omega Drive, Stamford, Connecticut USA

HyCal Model RTS-30, Platinum RTD
Intertechnology, 1 Scarsdale Rd.,
Don Mills, Ont.

Enercorp Model Precision Pt-100 RTD
P.O. Box 20, Station U, Toronto, Ont.

5. Sensor Mounting:

RTD sensors shall be installed in stainless steel wells, positioned at piping tees as noted in the system diagram. Silicone heat-conductive compound shall be used to ensure good thermal contact between the element and the system fluid. Metal junction boxes or heads shall be affixed to the thermal wells in order to protect the sensor unit wiring and terminal block junctions. These boxes shall be designed to allow access to the temperature sensors for service and replacement.

4. Recommended Instrumentation Specifications - cont'd

5. Sensor Mounting - cont'd

A packing nut and gland shall be used to affix the temperature sensor to the thermal well and to reduce the external ambient heat effect on the sensor.

For thermowells installed in cold water lines (T-3, T-4, T-5 and T-8 in system diagram), a waterproof sealant must be applied around the point at which the sensor wires pass through the packing nut in order to prevent condensation in the well and subsequent failure of the element.

6. System Status Panel

Provide a system status panel as illustrated on the "Closed Loop" diagram. Panel to be approximately 250mm high x 300mm wide, black or dark colour "Lamacoid" surface with engraved lettering 12mm high, complete with "green" running lights and "red" alarm lights and alarm reset. Provide cut-outs for recessed mounting of elapsed time counter and event counter.

7. Freeze Protection Thermostat

Equal to "Penn" series A19, single-pole, single-throw, 110V, to break on temperature fall, range adjustable from -15°C to 40°C with manual reset button. Unit complete with bulb well and packing nut assembly, 12.5mm NPT adaptor and 110mm long stem. Install in thermal well in collector return line and wire to stop primary circuit pump. Provide also wiring to status panel for alarm annunciation.

4. Recommended Instrumentation Specifications - cont'd

8. High Limit Thermostat

Equal to "Penn" A19 ANC complete with rainproof enclosure, range 38°C to 121°C, set at 95°C complete with capillary sensing bulb and well installed at collector outlet. Wire through latching relay to collector system status panel to annunciate high collector temperature conditions.

9. Hi-Lo Pressure Alarm

Equal to "Winters" double contact gauge, 150 mm dial, range 0-700 kPa, complete with relays. Alarm pointers adjustable throughout range, complete with pet cock. Wire to status panel to annunciate high and low pressure alarm conditions.

10. Pump Starters

Provide wiring from pump starters to the status panel running lights.

11. Pressure Gauges

150mm diameter face, black finished steel case, complete with brass pet cock. Range to suit installation parameters, equivalent to "Trerice" or "Winters". Install complete with switchover valves to measure pump suction and discharge pressure of primary and secondary circuits.

4. Recommended Instrumentation Specifications - cont'd

12. Overflow Containers

Provide overflow containers, permanently installed, to receive fluid discharge from pressure/temperature relief valves of primary and secondary water circuits. Minimum capacity: 10 liters.

13. Elapsed Time Meter

Electro-mechanical, 110 volt, AC synchronous motor-driven counter with non-resettable, 6-digit hour and tenths of hour indication, CSA approved. Equal to Bach Simpson #1357 ETIF.

14. Event Counter

Electro-mechanical, 110V, non-resettable, minimum 6-digit readout, CSA approved. Equal to "Hecon" AO-040. Minimum height of digits: 5mm. CSA approved.

5. Operational Monitoring - Installed Costs - (based on 1983 rates)

1. Temperature Read-Out

Sensors with electrical connection box:(8)	$ 800.00
Stainless steel wells (8 such):	$ 120.00
Digital Temperature Read-Out:	$ 550.00
Rotary Selector Switch:	$ 200.00
Panel with Engraving:	$ 250.00
Materials for Wiring:	$ 350.00
Labour to Install: 30 hrs.@ $25.00:	$ 750.00
MATERIAL AND LABOUR:	$3,020.00

2. Status Panel

Freeze Protection Thermostat and Well:	$ 72.00
High Limit Thermostat and Well:	$ 160.00
Hi-Low Pressure Switch/Gauge:	$ 120.00
Flow Switch:	$ 60.00
Elapsed Time Meter:	$ 40.00
Event Counter:	$ 20.00
Panel with Engraving and Pilot Lights:	$ 360.00
Materials for Wiring:	$ 320.00
Labour to Install: 20 hrs. @ $25.00:	$ 500.00
MATERIAL AND LABOUR:	$1,652.00

5. Operational Monitoring - Installed Costs - cont'd

3. Miscellaneous

Thermo-wells for balancing collector banks (ten such):	$ 100.00
Pressure Gauges c/w Pet Cocks and Switch-over valves (two such):	$ 90.00
Overflow Receivers (two such):	$ 60.00
Labour to Install: 18 hrs. @ $25.00:	$ 450.00
MATERIAL AND LABOUR:	$ 700.00
TOTAL - ALL SYSTEMS:	$5,372.00
Plus 10% Overhead:	$ 537.20
	$5,909.20
Plus 10% Profit:	$ 590.92
TOTAL OPERATIONAL MONITORING:	$6,500.12

The capital costs for systems using minimal instrumentation only would include:

- Eight thermometers - installed:	$ 640.00
- Freeze protection wired to stop pump:	$ 200.00
- Pressure gauges - installed:	$ 200.00
	$1,040.00
Plus 10% Overhead:	$ 104.00
	$1,144.00
Plus 10% Profit:	$ 114.40
Total Installed Costs - "Minimal System":	$1,258.40

Cost difference between the proposed "Operational Monitoring" system and a "Minimal"system:	$6,088.70
Less:	$1,258.40
	$4,830.30

6. Percentage Operational Monitoring to Overall Solar System Capital Costs

The percentages by which capital costs are increased by the incorporation of the proposed Operational Monitoring System are tabled below:

No. of Collectors @ \$1.80 m^2 Each	Cost per m^2 Collector Installed	Solar System Capital Cost	Percentage Operational Monitoring to Overall Cost
60	\$800	\$ 86,400	5.3%
80	\$790	\$113,760	4.1%
100	\$780	\$140,400	3.3%
120	\$770	\$166,320	2.8%
140	\$760	\$191,520	2.5%
160	\$750	\$216,000	2.2%
180	\$740	\$239,760	2.0%
200	\$730	\$262,800	1.8%

The above assumes a constant cost for the Operational Monitoring System. Slight variations are to be expected, depending upon actual design configurations.

OPERATIONAL MONITORING AND MAINTENANCE

PHASE II - SOLAR ASSISTED DOMESTIC HOT WATER HEATING SYSTEMS

MEDIUM TO LARGE CAPACITY DRAIN-BACK SYSTEMS

REVISED MARCH 1984

OPERATIONAL MONITORING AND MAINTENANCE

PHASE II - SOLAR ASSISTED DOMESTIC HOT WATER HEATING SYSTEMS

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INTRODUCTION

The general concept of Operational Monitoring and Maintenance is to provide methods of ensuring:

- that the solar heating system is operating as designed.
- that operational problems and system breakdowns are detected as early as possible.
- that action is taken before serious damage and expensive repairs are incurred.
- that a long life expectancy of the system can be realized.
- that long-term operation and maintenance costs are kept to a minimum.
- that maintenance is performed on a regular, scheduled basis.

MONITORING STRATEGY

The methodology by which monitoring is accomplished for the engineered domestic water solar heating systems should take into account:

- that solar system instrumentation of sufficient accuracy and dependability is provided, to facilitate performance monitoring suitable for start-up, fine tuning, routine inspection, performance verification and trouble shooting.
- that a visual or audible alarm is provided to annunciate upon abnormal conditions.
- that operational check lists and maintenance schedules become part of a regular maintenance program.
- that energy monitoring can be integrated without unnecessary duplication of monitoring hardware.

OPERATIONAL MONITORING AND MAINTENANCE

PHASE II - SOLAR ASSISTED DOMESTIC HOT WATER HEATING SYSTEMS

DRAIN-BACK SYSTEMS

1. Description of Systems:

Systems in this category may include installations with a minimum of 60 collectors. These systems normally would be custom designed and may vary to a degree in concept depending on the application and preferred design procedures. Except for these variations, the design and operation of the drain-back systems can be described as follows:

The drain-back concept employs a primary/secondary heating system. The primary circuit consists of a vented loop containing chemically treated, and in some cases de-ionized water, as the heat transfer liquid which is circulated through the solar collectors and a heat exchanger During pump off cycles, all water contained in the primary loop runs back by gravity through collector feeds and collector returns to a receiver located at the lowest part of the drain-back loop. The secondary circuit is represented by the domestic water to which the heat contained in the primary circuit is transferred.

The two heat transfer methods most commonly used are:

1. Shell and tube or plate type converter with pumped primary and secondary circuits.
2. Tube bundle insertion into storage tank without secondary circuit pump.

Local environmental and health codes may require these heat exchangers to be double wall construction, to prevent cross-contamination between the primary circuit and the domestic water.

1. **Description of Systems** - cont'd

The water contained in the primary circuit is circulated by one or more pumps whenever heat is available at a temperature suitable to provide domestic water heating. Circulation is initiated by a controller sensing temperatures at the collectors and in the solar storage tank.

The primary circuit must develop a static head to initially pump the water up to the collector. During operation, a combination of static head and pipe friction is encountered as the collector return system fills with water and a degree of syphon action develops. Some designs incorporate flow regulators at each collector bank to ensure uniform flow through all and each collector bank.

A high limit thermostat, usually installed in the drain- back receiver, stops the primary circuit pump whenever abnormally high temperatures are experienced.

Drain-back systems sometimes are vented to atmosphere at the drain-back receiver, or they can be designed as a "semi-closed" loop incorporating a pressure relief valve and vacuum breaker as shown in the circuit diagram.

The solar storage tank contains domestic water, preheated by the solar system, at temperatures which vary according to the amount of solar energy absorbed by the collectors and delivered, and the rate of domestic water consumption.

Auxiliary domestic water heating normally is provided in separate storage tank-heaters installed in series, downstream of the "solar storage Tank".

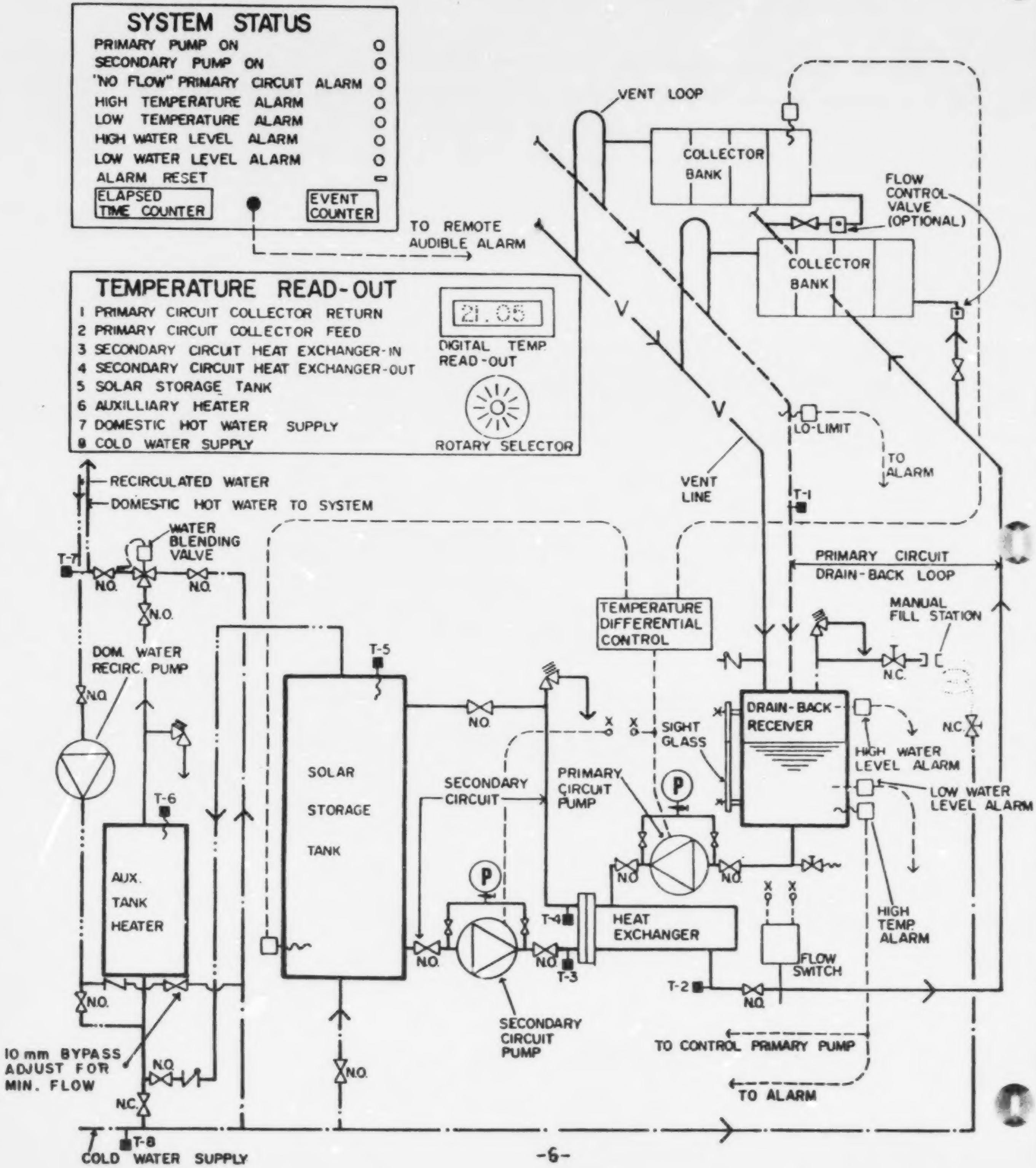
1. Description of Systems - cont'd

Solar System Diagram

The following diagram, entitled "DRAIN-BACK DOMESTIC HOT WATER SOLAR SYSTEM" indicates instrumentation necessary for operational monitoring. The circuit diagram shown reflects the most commonly engineered closed loop system. Certain instrumentation modifications may be required for other types of circuits.

DRAIN BACK

DOMESTIC HOT WATER SOLAR HEATING SYSTEM



SYSTEM STATUS

- PRIMARY PUMP ON ○
- SECONDARY PUMP ON ○
- "NO FLOW" PRIMARY CIRCUIT ALARM ○
- HIGH TEMPERATURE ALARM ○
- LOW TEMPERATURE ALARM ○
- HIGH WATER LEVEL ALARM ○
- LOW WATER LEVEL ALARM ○
- ALARM RESET ▭
- ELAPSED TIME COUNTER
- EVENT COUNTER

TEMPERATURE READ-OUT

1. PRIMARY CIRCUIT COLLECTOR RETURN
2. PRIMARY CIRCUIT COLLECTOR FEED
3. SECONDARY CIRCUIT HEAT EXCHANGER-IN
4. SECONDARY CIRCUIT HEAT EXCHANGER-OUT
5. SOLAR STORAGE TANK
6. AUXILLIARY HEATER
7. DOMESTIC HOT WATER SUPPLY
8. COLD WATER SUPPLY

2. Instrumentation Guideline

1. Temperature Indicators:

Temperature indicators are necessary for routine checks and to afford detection of abnormal operating conditions:

Experience has shown that commercially available bimetallic or liquid-filled thermometers are of little use to the solar system operator. Such thermometers are usually out of calibration to a point where a comparison of fluid temperatures becomes meaningless.

Both the primary and secondary circuits have wide ranges in operating temperatures, eg: 5°C to 90°C. The relative temperatures, or temperature differentials, between circuit supplies and returns and the approach temperatures between primary and secondary circuits, however, are very small in drain-back solar heating systems:

- During maximum insolation, the temperature difference between collector feed and return is usually 5°C to 8°C.
- The average difference on a sunny day between collector feed and return is 2.5°C to 4°C.
- The temperature differential between secondary circuit supply and return fluctuates between 0°C and 10°C.

and

- The approach temperature between primary circuit (collector loop) return and secondary circuit supply (leaving heat exchanger) usually fluctuates between 0°C and 10°C.

2. Instrumentation Guideline - cont'd

1. Temperature Indicators - cont'd

In addition to knowing the temperature levels of the primary/secondary circuits, it is the knowledge of the foregoing temperature differentials which indicates to the operator whether or not the solar heating system is operating correctly. Because the temperature differentials within the primary and secondary loops are small (0-10°C) but may occur anywhere within the system operating range of 5-95°C, temperature sensors of exceptional accuracy and linearity are required to permit meaningful measurements. For a typical operating temperature differential of 5°C, two measurements of plus or minus 0.5°C accuracy will produce a reading within 1°C, or 20% of the actual value. For the purpose of performance monitoring, this accuracy is considered a minimum standard.

Principle Types of Temperature Sensors

(a) Liquid-Filled:

There are many types of liquid-filled temperature indicators and sensors, the most common of which are mercury or coloured-alcohol glass stem thermometers. The principle by which these operate is the expansion of liquid volume that occurs with increasing temperature. By using a large bulb and a small capillary the effect is magnified to give a direct visual reading along a linear scale. Typical accuracy of glass stem thermometers is plus or minus 2°C and may depend upon immersion depth and ambient temperature. Because of these restrictions, liquid-filled thermometers have little application in solar system performance monitoring other than as general indicators.

2. Instrumentation Guideline - cont'd

1. Temperature Indicators - cont'd

(a) Liquid-Filled - cont'd

If a single thermometer is used to access several measuring points, the comparative readings will be more meaningful than if separate, unmatched, or uncalibrated thermometers are used.

(b) Mechanical (Dial)

Widely used in commercial applications because of their durability and portability, most mechanicl thermometers function by using the different expansion co-efficients of dissimilar metals to bend or distort a bimetallic element. In their simplest form two metals with very different expansion properties are bonded together, fixed at one end, and attached to an indicator needle at the other. Bimetallic thermometers generally have a rapid response time and an easily readable dial but typical accuracies of plus or minus 2°C and the non-repeatability of readings due to linkage backlash and bimetal aging limit their usefulness in solar system monitoring. As with the liquid-filled type, it is better to use a single mechanical thermometer for comparative readings than to rely upon the measurements from separate units.

(c) Thermocouple

Thermocouple sensors are employed in many types of temperature measurement systems; they are available in a wide variety of physical forms, are durable and inexpensive, and often permit a wide temperature range.

2. Instrumentation Guideline - cont'd

1. Temperature Indicators - cont'd

(c) Thermocouple - cont'd

Thermocouple sensors measure the changes in voltage produced by the heating of the junction of dissimilar metals or alloys. This voltage increases with temperature but in a very non-linear fashion. The voltage changes are extremely small -- in the order of tenths of a millivolt per degree centigrade. Thus, special electronic instrumentation and stable references are required to obtain usable temperature indication from thermocouple sensors.

In addition, special wiring procedures must be used when attaching remote sensors in order to ensure that unintentional junctions and voltages are not introduced into the system. While properly constructed thermocouple systems may achieve an accuracy of plus or minus 1°C or better, their extremely small signal, their lack of stability, and their requirements for critical wiring procedures make them more suitable for wide-temperature-range industrial applications than for solar hot water systems.

(d) Thermistor

Thermistor sensors find wide application in temperature measurement and control systems because of their speed, their relatively high output, their availability and their low price. All thermistors are composition resistors whose resistance decreases with increasing temperature.

2. Instrumentation Guideline - cont'd

1. Temperature Indicators - cont'd

(d) Thermistor - cont'd

This phenomenon is non-linear, (often exponential), requiring that each sensor type be matched with a specifically adapted readout/control device. The sensors require some power to operate and self-heating can be a problem.

In solar domestic hot water control systems, 2-wire thermistor sensors have performed adequately. For accurate temperature measurement (plus or minus 1°C), lead-length and lead-temperature compensation features must be incorporated by means of 3 or 4 wire leads to each sensor point.

Largely because of the non-standard manufacturer-specific nature of thermistor sensors, their use in multiple-point performance monitoring of solar systems is not recommended.

(e) Semi-conductor

A recent introduction to the temperature measurement field, the "IC" (integrated-circuit) sensors, such as the LM-334, rapidly are becoming accepted in a number of control and monitoring applications. While the detailed internal operations of such devices are quite complex, most are designed to produce a voltage or current which increases with sensor temperature, with low sensitivity to supply voltages, lead-lengths etc.

2. Instrumentation Guideline - cont'd

1. Temperature Indicators - cont'd

(e) Semi-conductor - cont'd

Several manufacturers have settled upon a standardized output that produces approximately 10 mV per degree Kelvin; thus at 0°C (273.16°K) the output is 2.732V and at 100°C (373.16°K) the output is 3.732V. The devices have good linearity, give a high output and are quite inexpensive.

Semi-conductor sensors require a power supply, are self-heating, and have relatively slow response. Typical installed accuracies are plus or minus 1°C.

At present, IC sensor instruments are not recommended for monitoring the temperature of solar domestic hot water systems because no independent standard exists for their calibration, accuracy and stability. It is likely that this situation will change in the future and that IC sensors will become much more widely used.

(f) RTD Platinum

Accepted for many years as the "standard" temperature sensor, RTD Platinum (Resistance Temperature Detection) devices display an increasing resistance with increasing temperature. This is a property shown by most pure metals; platinum is chosen because of its exceptional long-term stability and its tolerance to high temperatures.

2. Instrumentation Guideline - cont'd

1. Temperature Indicators - cont'd

Of the five main types of temperature sensors (liquid filled, bimetallic, thermocouple, resistance temperature detectors [RTD's], and semiconductor), the RTD devices (particularly platinum RTD's) possess the best combination of initial accuracy, linearity, stability and industry standardization.

The use of standardized resistance element values and calibrations is of great advantage in permitting the interchanging of sensors and measurement instrumentation. At present, the DIN 43760 standard "alpha=0.0385/ohm/°C" is most commonly used. Using "off-the-shelf" RTD elements, wiring, switches and digital indicators, the target of overall system accuracy of plus or minus 0.5°C is readily attainable.

Caution must be observed during the selection and installation of such equipment so that lead-length and lead-temperature variations are compensated for (usually by 3 or 4 wire sensors) and that junctions and wiring are performed to the manufacturer's specifications.

For temperature measurements of a less critical nature (such as solar storage tank or supply cold water) the same measurement electronics can be used with lower precision (and less costly) RTD sensors.

2. Instrumentation Guideline - cont'd

1. Temperature Indicators - cont'd

It is recommended that all temperature sensors be installed in stainless steel thermometer wells located at piping tees in the solar system circuits. This would allow service, replacement and calibration procedures to be accomplished without loss of system fluid. Sensors should be installed in the wells with silicone thermal conductive compound to ensure accurate readings.

2. Provisions Made for Collector Bank Water Balancing

Provisions should be made at each individual collector bank to allow measurement of the collector return temperature. During system commissioning, this will facilitate water balancing in an effort to achieve uniform flow through the collectors. The balancing would be performed on a sunny day with the system operating. Ideally, once balanced, each collector bank should indicate the same temperature differential between feed and return. During operation, periodic checks should be made to verify that equal flow exists. It is recommended, therefore, that thermal wells be installed at the outlet of each collector bank, suitable for the insertion of a portable electronic probe.

As an alternative to the above, constant flow regulators could be installed in each collector bank branch circuit supply. This ensures that an equal amount of water circulates through each individual collector bank. With this concept, the pressure drop through the flow balancing valve must be added to the pump head when initially selecting the primary circuit pump.

2. Instrumentation Guideline - cont'd

3. High Temperature Alarm

There are several reasons why the primary circuit can reach abnormally high temperatures:

1. Over-collection of solar heat relative to domestic water load.
2. Secondary pump failing to operate in unison with primary pump; therefore solar heat collected cannot be transferred to the secondary circuit or to the domestic water.
3. Blockage or excessive fouling of heat exchanger tubes.

A high limit temperature sensor installed in the drain-back receiver shall cycle the primary circuit pump 'off' whenever temperature in excess of 90°C are experienced. An audible alarm should annunciate the high temperature conditions.

4. Pressure Gauges:

(a) Primary Circuit Pump

A pressure gauge through switchover valves should be installed across the primary circuit pump, capable of measuring pump suction or discharge pressure.

In a case where the primary system is vented to atmosphere, the pressure gauge will read between 10 and 20 kPa when the pump is off (pressure equivalent to water column measured vertically between gauge and water level in receiver).

2. Instrumentation Guideline - cont'd

4. Pressure Gauges - cont'd

(a) Primary Circuit Pump - cont'd

Where a "semi-closed" loop is adopted (as shown on the system diagram), the pressure gauge will read anywhere between 10 kPa and the relief valve pressure setting, depending upon the fluid temperature. Upon start-up, as the collector feed line fills with water, the discharge pressure will increase gradually to overcome the static head of the system and the pressure differential imposed by the flow control valves. As the system starts returning water to the drain-back receiver, the discharge pressure will reduce due to syphon action, depending on the design concept of the collector return system. The discharge pressure will settle down during operation to indicate a combination of static and dynamic pressure.

5. Primary Circuit Flow Switch

When the primary circuit pump is operating, flow should exist through the primary loop. If, for any reason, the pump is not capable of developing discharge pressure sufficient to sustain circulation, the solar system is rendered entirely ineffective.

It is recommended that a flow switch be installed in the primary circuit, wired to the system status panel to annunciate a no-flow condition. The alarm would be wired so as to be effective only if a no-flow condition occurs while the primary pump is running.

2. Instrumentation Guideline - cont'd

6. Low Water Level Alarm

A low water level could occur due to:

- Natural evaporation of primary circuit fluid.
- Leak in circuit piping or collectors.
- Cross-contamination between primary and secondary circuits.

A low water condition can result in primary circuit pump cavitation and pump over-heating, leading to ineffective operation and potential material damage.

It is recommended that a low water level probe be installed in the drain-back receiver, wired to sound an alarm whenever a low water level occurs in the drain-back tank.

7. High Water Level Alarm

A high water level could occur due to:

- Overfilling of primary circuit system
- Cross-contamination between secondary and primary circuits.

A high water condition can result in restricted venting of the drain-back lines and collectors. This problem could lead to residual water remaining in the primary loop when the pumps are off, causing system inefficiency and possible freeze-up of the collectors and lines during cold weather.

2. Instrumentation Guideline - cont'd

7. High Water Level Alarm - cont'd

A high water level probe should be installed in the drain-back receiver to give an audible and visual alarm whenever excessive water levels are encountered.

Provision should be made to protect the high-level detector probe from nuisance alarms or damage in the design of the inlet configuration connecting collector and return line to the drain-back receiver.

8. Elapsed Time Indicator - Secondary Circuit Pump

The provision of an elapsed time meter showing accumulated run time of the secondary circuit pump will give the operator reasonable indication of the solar system performance. Control system problems, and especially abnormal continuous operation with resulting energy waste, may be detected by regular observation of run time.

The secondary circuit pump should be wired through the flow switch installed in the primary circuit. Whenever flow exists in the primary circuit, the secondary circuit pump will operate.

9. Event Counter

The event counter is an electro-mechanical device indicating the number of secondary circuit pump on-off cycles. This relatively inexpensive device would be very useful to set up initially the temperature differential settings activating and de-activating the circulating pumps. In addition, the event counter could be useful in detecting abnormal and erratic cycling due to intermittent wiring connections.

2. Instrumentation Guideline - cont'd

10. Freeze Protection

Automatic frost protection must be considered for the primary circuit. The frost protection thermostat should be installed in the collector return line and wired to stop the primary circuit pump in the event that fluid temperatures below 5°C are encountered. Low temperature alarm annunciation should be incorporated at the system status panel.

3. Operational Monitoring and Maintenance Procedures

The type and extent of instrumentation provided for operational monitoring is considered to be that necessary to furnish the operator with sufficient information to make routine diagnoses, to calibrate and adjust the controls, and to ensure annunciation of alarm conditions.

The "Operator's Check List" should be used to record operating conditions and to perform operational analyses. Certain modifications and amendments may be required to the check list in order to suit the actual system design concept. The frequency of use depends upon the complexity and performance record of the solar system.

The "Maintenance Schedule" separates the system into components and lists the recommended procedures and frequency of each maintenance task. This schedule may have to be expanded or altered in order to accommodate other design concepts or specific manufacturer's recommendations.

The Operational Problems Chart serves as an aid to system trouble-shooting.

3. Operational Monitoring and Maintenance Procedures - cont'd

The use of the "Operator's Check List" may help in the detection of operational problems. The "Operator's Guidelines" reflects system concepts illustrated in this manual and explains the operation of individual control and monitoring components. It will help the operator to properly control and monitor the system, to identify problems, and to perform the necessary corrective measures.

OPERATOR'S CHECK LIST

Medium-to-Large DRAIN-BACK SOLAR WATER HEATING SYSTEM

PROJECT: SYSTEM MANUFACTURER:

OPERATOR: MONTH: YEAR:

Date and Time	Weather (Check One)			Approx. Outdoor Temp. °C	Power On Yes or No	Pumps On		Temperatures (°C)								System Press. kPa Pr.Cct	Elapsed Time Hours & Tenths of Hours	Interval Counter Total Counts	System Alarms					Overflow Containers (Wet/Dry)		Water Added Yes or No	Visible Leaks Yes or No
	SUNNY	PARTLY SUNNY	CLOUDY NO SUN			Primary	Secondary	Heat Exchangers				Storage Tanks		Water Supply					High. Limit Yes or No	Low Limit Yes or No	Liquid Level Yes or No		No Flow Yes or No	Clos. Loop	Solar Stor-age Tank		
								Primary		Secondary																	
								IN T-1	OUT T-2	IN T-3	OUT T-4	Solar T-5	Aux. T-6	Hot T-7	Cold T-8						Hi	Lo					

MAINTENANCE SCHEDULE - MEDIUM-TO-LARGE DRAIN-BACK SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	COMMENTS
Complete System	Operational Checklist	x	x	x		x	Initially more frequently, then as required.
COLLECTORS:							
Panels	Inspect for leaks, breakage, overheating panels.			x			On sunny days (pump running.
	Manage snow		x				Winter months only
Glazing	Wash externally with warm soapy water.					x	More often if dirty.
Vents	Check and clear vent holes.					x	Also if chronic condensation is observed.
Supports/Mounting and Fasteners	Check structure, tighten bolts, inspect isolation pads, touch-up where corrosion is evident					x	
Piping	Inspect hangers and supports. Adjust, check pipe slopes					x	Resupport pipes if sagging
	Measure drain-back time.				x		Particularly important before winter season
	Check flow balancing for each collector array. Complete balancing procedures are outlined in the Solar Programs Office Commissioning and Monitoring Procedures Documents					x	Temperature at inlet/outlet of each array can be measured with calibrated electric thermometer near noon on a sunny day (with system running)

MAINTENANCE SCHEDULE - MEDIUM-TO-LARGE DRAIN-BACK SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
COLLECTORS: (cont'd)							
Piping (cont'd)	Verify pipe jackets and insulation. Repair weatherproof jackets where necessary. Replace wet fibreglass insulation. Inspect for UV degradation of plastic pipe jackets.					x	
	Check pipe connections and roof penetrations					x	Use 95-5 solder for copper pipe repairs
Control Modules	Verify wiring/connections and mounting of sensors				x		
DRAIN-BACK RECEIVER	Check water levels. Replenish with softened treated water			x			Also upon alarm signals
	Clean, descale, remove sediment and flush					x	Including probes
	Inspect tank insulation				x		
Level Sensors	Check and clean sensors. Operate manually					x	
PUMPS AND MOTOR CONTROLS							
Motors	Check amps, temperature, RPM					x	
Contactors and Switches	Inspect and torque connections. Check for pitting. Replace points.					x	
Bearings	Listen for vibration/noise. Lubricate				x		Where applicable

MAINTENANCE SCHEDULE - MEDIUM-TO-LARGE DRAIN-BACK SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
PUMPS AND MOTOR CONTROLS (cont'd)							
Seals	Check carbon/ceramic, O-ring and mechanical seals for noise, wear and leakage.			x			As per manufacturer's recommendations. Replace if leaking
Couplings	Inspect for play. Tighten if loose			x			
Mounting and Alignment	Verify. Adjust if required					x	
Impellers	Listen for noise. Measure developed pressure				x		
HEAT EXCHANGER	Measure & record pressure drop through convertor			x			
	Clean and inspect units as per manufacturer's recommendations. Service if pressure drop exceeds initial value by 20%.					x	Shell & Tube Exchangers: If floating heads, rod-through tubes. If bundle type use chemical cleaning & flushing. If plate type, disassemble and clean using fibre brush with soda ash/detergent solutions.
	Replace gaskets						As necessary.
STORAGE TANKS	Inspect tank insulation					x	
	Inspect linings for cracking, deformation or melting. Storage tank lining to be identified and labelled.						Repairs should be performed per manufacturer's recommendations.

MAINTENANCE SCHEDULE - MEDIUM-TO-LARGE DRAIN-BACK SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
STORAGE TANKS (cont'd)							
	Typical linings for tanks include directly applied cement (sometimes referred to as 'stone-lined'), cement applied to welded mesh, calcium aluminate coatings (eg: "Alcrete"), skin-tight copper linings, epoxy finishes and vinyl plastic sheet inserts.						Different tanks have significantly different maximum temperature limitations and repair and maintenance requirements. All can benefit from frequent flushing and cleaning.
	Verify condition of magnesium anodes and other corrosion protection devices.					x	Where installed.
Cement Lined	Drain, open manhole, carefully inspect lining. Patch with material/method recommended by manufacturer. Remove debris, flush, replace gasket if necessary and refill.					x	During winter months, preferably on cloudy day. Provide adequate lighting and ventilation.
Glass Lined	Inspect. Repair/replace as per manufacturer's recommendations					x	Required only if blocked or if corrosion evident in water supply can be traced to tank.
Plastic (Vinyl or Epoxy)	Inspect for damage, leaks or discolouration. Drain, remove debris then flush. Repair as per manufacturer's recommendations.					x	Water should not penetrate behind these liners.
Probes & Sensors	Disconnect, clean and manually test if possible					x	Well-mounted units can be accessed externally.

MAINTENANCE SCHEDULE - MEDIUM-TO-LARGE DRAIN-BACK SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
PIPING ACCESSORIES							
Primary and Secondary Loops	Verify mounting, hangers and slopes. Check for leaks and damaged or wet insulation					x	Repair as required
Valves	Manually operate. Check for stem leaks etc. Inspect glands and seals. Verify that they are returned to balanced or normal (NO/NC) operating positions					x	Replace if necessary. Valves should have tags attached, stating their function & normal setting
Check Valves/ Vacuum Breakers	Open, clean and verify operation where possible. Check springs on spring-operated valves.					x	
Strainers	Open, remove basket, clean and flush			x		x	More frequently if indicated by excessive pressure drop, and during start-up
Water Filters	Monitor pressure drop.			x			Replace media/cartridge as required.
Relief Valves	Inspect if outlet port & discharge pipe are clear. Manually operate levered type. Verify setting if adjustable.					x	Replace overflow container under outlet pipe (if present).
Air Vents	Ensure floats and seals are clean on serviceable units. Check that vent caps are loosely screwed on. Inspect for leaks.				x		Not present in many drain-back systems.

MAINTENANCE SCHEDULE - MEDIUM-TO-LARGE DRAIN-BACK SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
PIPING ACCESS. (cont'd) Fluids	Check level, top-up with filtered softened water.			x			As per manufacturer's recommendations. Evaporative losses should normally be small.
	Inspect for presence of colour or suspended solids.			x			
	Conduct program of chemical tests and treatment as formulated for the particular solar system and local water conditions.		x				Or as directed by water treatment company. Fluid may have to be completely replaced every few years, depending upon the water quality and the behaviour of the solar system.
CONTROLS AND MONITORING INSTRUMENTATION							
Differential Controller	Verify correct system status indications for "OFF", "MANUAL" & "AUTOMATIC" control positions. Check that pumps are actually running per control indications.			x			
	Turn power off, then reset to verify controller start-up operation.			x			Preferably on sunny day.
	Measure and adjust controller "ON" and "OFF" temperature differentials					x	Certain controllers give direct electronic or digital readouts; others will require the placement of sensors in temperature baths to fully verify set points

MAINTENANCE SCHEDULE - SOLARTECH EVACUATED TUVE SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
CONTROLS AND MONITORING INSTRUMENTATION (cont'd)							
System Status Panel	Operate and reset all alarm and status-indication circuits (high water, low water, high temperature, low temperature etc.)				x		
	Check elapsed time meter & event counter for proper operation.			x			
Temperature Readout Panel	Record temperatures at all sensing points and verify (T-collector out T-collector in etc.)		x				Pumps must be circulating for several minutes before readings are taken.
	Withdraw sensors from wells and check as-installed calibration at ice-point & boiling point of water					x	Required at least once during lifetime of a system & more often if system uses sensors other than platinum RTD units.
Wiring (Power)	Check insulation near controllers, contactors & motors for signs of shrinking or brittleness. Inspect for physical damage of wire or conduit					x	Overheating of wire may be due to poor relay contacts, loose terminals or overloaded pump motor; check.
Wiring (Sensors)	Verify that junctions, protective conduits and shielding are intact. Loosen off and retighten terminal screws.					x	

OPERATIONAL PROBLEMS

SOURCE OF PROBLEM	POSSIBLE CAUSES	CONSEQUENCES	PERFORMANCE MONITORING
PUMP: Failure to operate when required to.	- Power off, Blown Fuse or Tripped Breaker - Not started through controller - Motor burned out - Impeller seized, blocked or disconnected. - Electrical Problem - Open cct.in collector sensor wiring - Short cct.in storage tank sensor wiring. - Control System Problems	- No collection of solar heat	Observation of Elapsed Time Indicator Observation of Event Counter Observation of Temperatures No-flow condition-alarm (flow switch)
PUMP: Operating when not required to:	- Control set to Manual Oper - Problem with sensors and/or controller - Faulty Switch - Faulty Wiring - Closed cct.in collector sensor wiring - Open cct.in storage tank sensor wiring - Control System Problems	- Reverse heat exchange - Freeze-up of collectors & primary circuit piping	Low Temperature Alarm Frost Protection Thermostat to shut down pump Observation of Elapsed Time Indicator Observation of Event Counter Observation of Temperatures
CONTROLLER: Not operating correctly	- Not adjusted correctly - Sensors loose - Faulty wiring - Faulty electronics - Faulty switches	- Inefficiency - Steam formation in collectors - Freeze-up of collectors and exposed piping.	High Temperature Pump Cut-off & alarm Low Temperature Alarm & Pump Cut-off Observation of Elapsed Time Indicator Observation of Event Counter Observation of Temperatures
NO CIRCULATION Pump Running	- Improper Venting - Low water level in receiver - Leak in piping system (fluid lost) - Part of piping system frozen up - Blockage in piping system - Impeller or drive defective	- No collection of solar heat - Pump cavitating - Pump overheating	No-flow Condition-alarm (flow switch) Observation of Temperatures Observation of Pressure Gauges Low water level alarm

SOURCE OF PROBLEM	POSSIBLE CAUSES	CONSEQUENCES	PERFORMANCE MONITORING
LEAK IN PIPING SYSTEM	- Incorrect solder joints - Expansion/contraction causing break - Frost Damage - Corrosion	- Loss of primary circuit fluid - No collection of solar heat - Poor or no water circulation - Pump Overheating	Low Water Level Alarm High Temperature Alarm Observation of Pressure Gauges Observation of Temperatures
FROST DAMAGE TO PRIMARY CIRCUIT	- Improper venting - Improper slopes of pipes and collector banks - Faulty controller, sensors, connection and wiring.	- No flow - Break in piping circuit - Loss of fluid	Frost protection thermostat to shut down pump and alarm
CROSS CONTAMINATION (for systems with direct heat exchanger)	- Leak in heat exchanger	- Primary circuit fluid transferred to domestic water circuit. - Dom.water transferred to primary circuit, followed by venting problems and possible freeze-up of primary loop	Low Water Level Alarm Observation of sight glass on drain-back tank. High Water Level Alarm
VENTING/DRAINAGE	- Improper slopes - Pipe buckling - Overfilling of drain-back receiver - Pipe blockage or constriction - Partial freeze-up	- Inefficiency - Freeze-up of collectors and piping	Observation of fill and drain-back cycle through sight glass is a partial solution; proper design of slopes and venting remains the primary consideration

OPERATOR'S GUIDELINES

1. SUNNY CONDITIONS AND PARTLY SUNNY CONDITIONS

The solar system should be cycling.

2. CLOUDY OR NO SUN CONDITIONS

The solar system may cycle only if the ambient outdoor temperature is sufficiently higher than the incoming water temperature or the temperature existing at the bottom of the solar storage tank.

3. POWER

If solar system does not perform as described under the above weather conditions, check main and branch circuit breakers.

4. PUMPS

1. Primary Circuit Pump

Primary circuit pump is activated and de-activated through differential temperature controller and should cycle as described under paragraphs 1 and 2. If NOT, check:

- Power connection, starter relay and wiring
- Differential controller setting
- Control sensor connections and transmission
- Controller
- High limit cut-out.
- Low limit freeze protection

7. CIRCUIT TEMPERATURES

Refer to "Drain-Back" diagram on Page 6.

- T-1 temperature should always be higher than T-2.
- The temperature differential should not exceed 5-8°C at maximum insolation. If higher temperature differentials exist, and the loop operates at a reduced flow rate, check for:
  - partially closed valves
  - dirty strainer
  - blockage
  - air lock
  - pump problems
- During sunshine periods with pump operating, a small temperature differential should always exist. If this is not the case, check:
  - valves closed in collector loop
  - No-flow for any reason
  - snow covered collectors
  - pump/impeller disengaged
  - freeze-up of collector loop

T-1 and T-2 temperature levels will fluctuate between 5°C and 95°C. Elevated temperature levels indicate large reserves of solar heated water. Without domestic water consumption, over-collection will result. This would lead to excessive loop temperature and pressure, and subsequent discharge of fluid through primary and/or secondary circuit relief valves.

7. CIRCUIT TEMPERATURES - cont'd

While the secondary pump operates, T-4 temperature should always be higher than T-3 temperature. If this is not the case, there may be no-flow through the secondary circuit, or a control system problem may exist leading to reverse heat exchange.

T-4 temperature should always read lower than T-1 whenever the pumps are operating.

Temperatures 1, 2, 3, 8 and possibly 5, may read near room temperature during periods when no flow exists through these circuits.

T-5 will read the temperature of the stored water. This temperature usually varies between 5°C (high domestic water draw without solar energy collection) and approximately 80°C (little or no domestic water drawn in combination with maximum solar energy collection).

T-6 will read the temperature of the domestic water in the auxiliary heating tank; normally set between 50°C and 60°C.

T-7 is the domestic hot water supply temperature, normally maintained between 45°C and 70°C.

T-8 reads incoming cold water temperature.

OPERATOR'S GUIDELINES

8. PRESSURE GAUGE PRIMARY CIRCUIT

The gauge reading the pump discharge pressure will indicate build-up of static head as the collector feed lines are filled with water. Upon resumption of normal circulation the discharge pressure will reduce as the collector return lines fill with water and syphon action is encountered.

The suction pressure, with atmospherically vented systems, will be near 0 kPa while the pump is in operation. When the pump is off, the gauge will read the pressure of the static head (water column measured vertically between the water level in the drain-back tank and the pressure gauge).

With "semi-closed" loop designs, both the suction and discharge pressures are elevated by the amount of pressurization at a given time.

9. PRESSURE GAUGE SECONDARY CIRCUIT

The pressure gauge on the secondary pump will fluctuate with the city water pressure and is used to observe pump performance.

10. FREEZE PROTECTION THERMOSTAT

This instrument should be set at 5°C; it protects the primary circuit from frost damage, stops the primary circuit pump, and sounds an alarm.

OPERATOR'S GUIDELINES

11. HIGH TEMPERATURE LIMIT THERMOSTAT

The high limit thermostat should be set to sound an alarm at temperatures in excess of 90°C; causes for which could be:

- Over-collection of solar heat relative to DHW consumption.
- No flow in secondary circuit.
- Blown or tripped circuit breaker of secondary pumps
- N.O. valves in secondary circuit in closed position.
- Heat exchanger problems.

12. LOW WATER LEVEL

Water must be added periodically to the primary circuit to make up for evaporative losses.

If the system is shut down frequently upon low water level condition, check for:

- Leaks in primary circuit
- High temperature limit setting too high (steam may be formed in collectors)
- Cross-contamination, primary circuit leaking water through convertor to secondary circuit (possible with semi-closed loop design only).

13. HIGH WATER LEVEL

A high-level water condition in the drain-back receiver may render the venting system ineffective. This situation could arise from overfilling of the primary loop or leakage through the heat exchanger from the domestic water side. The high-water level alarm would annunciate such a condition. Corrective action must be taken immediately.

14. CALIBRATION OF SENSORS

Calibration of all temperature sensors in their "as-installed" configuration can permit a system operator to monitor and maintain a solar domestic hot water circuit with significantly increased efficiency, accuracy and confidence. A simple calibration procedure using readily available materials may be performed at the ice-point of water (0.0°C) and at the boiling point of water (100°C), depending upon the atmospheric pressure:

> Crushed or broken ice is placed in a wide-mouth thermos containing cold water and the mixture is allowed to equilibrate. As long as significant quantities of both ice and water are present, the temperature of this mixture rapidly reaches 0.0°C (plus or minus 0.1°C) and is little affected by the local temperature or atmospheric pressure. One by one the temperature monitoring probes are withdrawn from their wells and placed in the thermos (near their original place of installation) and, after a settling period, the temperature is read at the central indicator unit.
>
> If 'zero' adjustment is possible, then each sensor channel is set to read 0.0°C while its corresponding probe is in the ice water bath; otherwise, a note of the observed error at 0°C (eg: T1 is 0.3° high, T2 is 0.5° low, etc) is made and clearly posted.

The same basic method is employed for the 100°C point except that water boiling vigorously on a hot plate is used and correction should be made for the atmospheric pressure.

14. CALIBRATION OF SENSORS - cont'd

The 'standard atmospheric' pressure is 101.3 kPa; the boiling point of water decreases approximately 0.3°C for each kPa reduction in pressure and increases 0.3°C for each kPa increase in pressure. At a local pressure of 100 KPa, therefore, water can be expected to boil around 99.6°C. The actual boiling point is thus determined and the sensor instrument error is adjusted or recorded as required.

4. Recommended Instrumentation Specifications.

.1 Temperature Read-Out

1. Digital Temperature Readout for Panel Mounting:

Range:	0°C to 100°C
Resolution:	0.1°C minimum
Accuracy:	0.1% of scale plus or minus one digit, (max. 0.2°C) at 20°C
Stability:	100 ppm/°C
Type:	Standard Platinum RTD (DIN 43760), 3 or 4 wire lead-resistance compensated
Sampling Time:	1 second maximum
Display:	7 segment L.E.D. or illuminated L.C.D., 12 mm digits minimum.
Other:	Readout to be protected from damage caused by: - open RTD sensor line - shorted RTD sensor line - RTD short to AC line
Suppliers:	Omega Engineering Model 199 RTD Meter 1 Omega Drive, Stamford, Connecticut,USA Doric Model 410A, 3½ Digit Indicator Intertechnology, 1 Scarsdale Rd., Don Mills, Ontario. Enercorp Model PDAW-48 RTD Indicator P.O. Box 20, Station U, Toronto, Ont. Thermo Electric Analogic/ELS RTD Indicators, 12 Rutherford, South Brampton, Ont.

4. Recommended Instrumentation Specifications.

2. Rotary Selector Switch for Panel Mounting

Selector shall be a ten-position, low resistance, ($\leq$0.01 Ω) double or triple pole, make-before-break switch with screw-terminals, suitable for RTD measurements.

Suppliers: Omega Engineering Model OSW3-10 Rotary
silver-contact RTD switch,
1 Omega Drive, Stamford, Connecticut,USA

Doric Model 409A, 10 Input, 3-pole
Pushbutton switch. Intertechnology,
1 Scarsdale Rd., Don Mills, Ont.

Enercorp 10-position, gold contact,
Rotary switch, P.O. Box 20, Station U,
Toronto, Ont.

3. Wiring

Wiring shall be 3 or 4 wire (depending upon sensor), unshielded PVC-jacketed cable with #22 AWG stranded, tinned conductors (Belden 8443 or equivalent). Wiring shall be routed, without junctions, from control panel to position near sensor installation, then by flexible conduit to connection box affixed to thermowell. Connection to RTD sensor wires shall be made using a screw terminal block. Exposed wiring shall be run in metal conduit.

Suppliers: Electro Sonic Inc.,
1100 Gordon Baker Rd., Willowdale, Ont.

Cesco Electronics Ltd.,
4050 Jean Talon W., Montreal, Que.

4. Recommended Instrumentation Specifications - cont'd

4. Temperature Sensors:

Sensors shall be Platinum RTD (DIN 43760) type, wire-wound or thin-film elements mounted in a rigid, heat-conductive shell, maximum diameter 6.4mm.

Minimum Performance Specifications:

Plus or minus 0.3°C at 0°C
Plus or minus 0.6°C at 100C

Suppliers:

Omega Engineering Model PR-12,
Platinum-100 RTD
1 Omega Drive, Stamford, Connecticut USA

HyCal Model RTS-30, Platinum RTD
Intertechnology, 1 Scarsdale Rd.,
Don Mills, Ont.

Enercorp Model Precision Pt-100 RTD
P.O. Box 20, Station U, Toronto, Ont.

5. Sensor Mounting:

RTD sensors shall be installed in stainless steel wells, positioned at piping tees as noted in the system diagram. Silicone heat-conductive compound shall be used to ensure good thermal contact between the element and the system fluid. Metal junction boxes or heads shall be affixed to the thermal wells in order to protect the sensor unit wiring and terminal block junctions. These boxes shall be designed to allow access to the temperature sensors for service and replacement.

A packing nut and gland shall be used to affix the temperature sensor to the thermal well and to reduce the external ambient heat effect on the sensor.

4. Recommended Instrumentation Specifications - cont'd

5. Sensor Mounting - cont'd

For thermowells installed in cold water lines (T-3, T-4, T-5 and T-8 in system diagram), a waterproof sealant must be applied around the point at which the sensor wires pass through the packing nut in order to prevent condensation in the well and subsequent failure of the element.

6. System Status Panel

Provide a system status panel as illustrated on the "Drain-Back" diagram. Panel to be approximately 250mm high x 300mm wide, black or dark colour "Lamacoid" surface with engraved lettering 12mm high, complete with "green" running lights and "red" alarm lights and alarm reset. Provide cut-outs for recessed mounting of elapsed time counter and event counter.

7. Freeze Protection Thermostat

Equal to "Penn" series A19, single-pole, single-throw, 110V, to break on temperature fall, range adjustable from -15°C to 40°C with manual reset button. Unit complete with bulb well and packing nut assembly, 12.5mm NPT adaptor and 110mm long stem. Install in thermal well in collector return line and wire to stop primary circuit pump. Provide also wiring to status panel for alarm annunciation.

4. Recommended Instrumentation Specifications - cont'd

8. High Limit Thermostat

Equal to "Penn" A19 ABC11 complete with well assembly, range 38°C to 116°C, set at 90°C complete with capillary sensing bulb and well installed in drain-back receiver. Wire through latching relay to shut down primary pump and to annunciate high temperature condition at status panel.

9. Low Water Level Alarm

Equal to "Penn" F63AC-1 liquid level float switch, wired to close circuit when liquid level falls below the required minimum level. Wire to annunciate low level condition at status panel.

10. High Water Level Alarm

Equal to "Penn" F63AC-1 liquid level float switch, wired to close circuit when liquid level rises above the maximum permissible level. Wire to annunciate high level condition at status panel.

11. Flow Switch Primary Circuit

Equal to "Penn" F61KB-11 to be installed in primary circuit, wired to sound alarm at "no-flow" condition while pump is operating. Wire, also, to initiate secondary pump operation when flow exists.

12. Pump Starters

Provide wiring from pump starters to the status panel running lights.

4. Recommended Instrumentation Specifications - cont'd

13. Pressure Gauges

150mm diameter face, black finished steel case, complete with brass pet cock. Range to suit installation parameters, equivalent to "Trerice" or "Winters". Install complete with switchover valves to measure pump suction and discharge pressure of primary and secondary circuits.

14. Overflow Containers

Provide overflow containers, permanently installed, to receive fluid discharge from pressure/temperature relief valves of primary and secondary water circuits. Minimum capacity: 10 liters.

15. Elapsed Time Meter

Electro-mechanical, 110 volt, AC synchronous motor-driven counter with non-resettable, 6-digit hour and tenths of hour indication, CSA approved. Equal to Bach Simpson #1357 ETIF.

16. Event Counter

Electro-mechanical, 110V, non-resettable, minimum 6-digit readout, CSA approved. Equal to "Hecon" AO-040. Minimum height of digits: 5mm. CSA approved.

5. Operational Monitoring - Installed Costs - (based on 1983 rates)

1. Temperature Read-Out

Sensors with electrical connection box:(8)	$ 800.00
Stainless steel wells (8 such):	$ 120.00
Digital Temperature Read-Out:	$ 550.00
Rotary Selector Switch:	$ 200.00
Panel with Engraving:	$ 250.00
Materials for Wiring:	$ 350.00
Labour to Install: 30 hrs.@ $25.00:	$ 750.00
MATERIAL AND LABOUR:	$3,020.00

2. Status Panel

Freeze Protection Thermostat and Well:	$ 72.00
High Limit Thermostat and Well:	$ 72.00
Two Level Probes and Wells:	$ 150.00
Flow Switch:	$ 60.00
Elapsed Time Meter:	$ 40.00
Event Counter:	$ 20.00
Panel with Engraving and Pilot Lights:	$ 360.00
Materials for Wiring:	$ 345.00
Labour to Install: 20 hrs. @ $25.00:	$ 500.00
MATERIAL AND LABOUR:	$1,619.00

5. Operational Monitoring - Installed Costs - cont'd

3. Miscellaneous

Thermo-wells for balancing collector banks (ten such):	$ 100.00
Pressure Gauges c/w Pet Cocks and Switch-over valves (two such):	$ 90.00
Overflow Receivers (two such):	$ 60.00
Labour to Install: 18 hrs. @ $25.00:	$ 450.00
MATERIAL AND LABOUR:	$ 700.00
TOTAL - ALL SYSTEMS:	$5,339.00
Plus 10% Overhead:	$ 533.90
	$5,872.90
Plus 10% Profit:	$ 587.29
TOTAL OPERATIONAL MONITORING:	$6,460.19

The capital costs for systems using minimal instrumentation only would include:

- Eight thermometers - installed:	$ 640.00
- Freeze protection wired to stop pump:	$ 200.00
- Pressure gauges - installed:	$ 200.00
	$1,040.00
Plus 10% Overhead:	$ 104.00
	$1,144.00
Plus 10% Profit:	$ 114.40
Total Installed Costs - "Minimal System":	$1,258.40

Cost difference between the proposed "Operational Monitoring" system and a "Minimal" system:	$6,048.70
Less:	$1,258.40
	$4,790.30

6. Percentage Operational Monitoring to Overall Solar System Capital Costs

The percentages by which capital costs are increased by the incorporation of the proposed Operational Monitoring System are tabled below:

No. of Collectors @ $1.80 M^2$ Each	Cost per M^2 Collector Installed	Solar System Capital Cost	Percentage Operational Monitoring to Overall Cost
60	$800	$ 86,400	5.3%
80	$790	$113,760	4.1%
100	$780	$140,400	3.3%
120	$770	$166,320	2.8%
140	$760	$191,520	2.5%
160	$750	$216,000	2.2%
180	$740	$239,760	2.0%
200	$730	$262,800	1.8%

The above assumes a constant cost for the Operational Monitoring System. Slight variations are to be expected, depending upon actual design configurations.

OPERATIONAL MONITORING AND MAINTENANCE

PHASE III - SOLAR ASSISTED DOMESTIC HOT WATER HEATING SYSTEMS

EVACUATED TUBE

MARCH 1984

OPERATIONAL MONITORING AND MAINTENANCE

PHASE III - SOLAR ASSISTED DOMESTIC HOT WATER HEATING SYSTEMS

EVACUATED TUBE SYSTEMS

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OPERATIONAL MONITORING AND MAINTENANCE

PHASE III - SOLAR ASSISTED DOMESTIC HOT WATER HEATING SYSTEMS

EVACUATED TUBE SYSTEMS

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OPERATIONAL MONITORING AND MAINTENANCE

PHASE III - SOLAR ASSISTED DOMESTIC HOT WATER HEATING SYSTEMS

EVACUATED TUBE SYSTEMS

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APPENDIX A:

Recommended Instrumentation Specifications for Evacuated Tube Systems (Medium-to-Large Capacity Systems)

APPENDIX B

Solar System Fluids

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INTRODUCTION

The general concept of Operational Monitoring and Maintenance is to provide methods of ensuring:

- that the solar heating system is operating as designed.
- that operational problems and system breakdowns are detected as early as possible.
- that action is taken before serious damage and expensive repairs are incurred.
- that a long life expectancy of the system can be realized.
- that long-term operation and maintenance costs are kept to a minimum.
- that maintenance is performed on a regular, scheduled basis.

MONITORING STRATEGY

The methodology by which monitoring is accomplished for the evacuated tube collector domestic water solar heating systems should take into account:

- that solar system instrumentation of sufficient accuracy and dependability is provided, to facilitate performance monitoring suitable for start-up, fine tuning, routine inspection, performance verification and trouble shooting.

- that a visual or audible alarm is provided to annunciate upon abnormal conditions.

- that operational check lists and maintenance schedules become part of a regular maintenance program.

- that energy monitoring can be integrated without unnecessary duplication of monitoring hardware.

OPERATIONAL MONITORING AND MAINTENANCE

PHASE III - SOLAR ASSISTED DOMESTIC HOT WATER HEATING SYSTEMS

EVACUATED TUBE SYSTEMS

BACKGROUND

Several systems employing evacuated tube collectors have been installed in Canada during the past four years.

Initially, the objective of these installations was to further the understanding of the performance and reliability of the evacuated tube collectors in domestic water, space and process water heating applications for the Canadian climate.

Most initial systems were prototypical in nature and various improvements to collector design, pipe circuitry and system controls were gradually introduced.

The main advantages of evacuated tube collectors over flat plate collectors are:

- Collection efficiency is higher during winter operation.
- Higher fluid temperatures can be reached, suitable for absorption cooling system integration and process heating applications.
- The ability to usefully collect heat from diffused radiation.
- Lower flow rates, reduced pump horsepower and piping with smaller diameters.

To-day, both packaged DHW systems and large capacity engineered systems are approved for installation under the PUSH program, involving the following collector manufacturers:

Manufacturer	Product
Solartech Ltd. 21 Prince Andrew Place Don Mills, Ont.	SOLARTECH ETC MODULE

BACKGROUND - cont'd

Manufacturer	Product
SOL-PRO Inc. 5368 13e Avenue, Rosemount Montreal, Quebec	SOL PRO E-100

The above two products vary greatly in collector design, required system circuitry and control strategy and will require independent analyses.

This Manual is therefore divided into two parts:
PART A: Solartech ETC Module Evacuated Tube Systems
PART B: SOL•PRO E-100 Evacuated Tube Systems

(A) SOLARTECH ETC MODULE EVACUATED TUBE SYSTEMS

1. Collector Module

The Solartech ETC Module is a drain-back liquid collector using Owens-Illinois evacuated tubes. Each module consists of eight evacuated glass tubes installed in parallel through sockets into a common supply/return manifold located at the bottom of the collector. Behind the tubes is a compound parabolic cusp reflector fabricated from a thin sheet of polished aluminum which is covered with a tedlar film to prevent oxydation.

The tubes are double glazed; a vacuum exists between the two hermetically sealed glass cylinders. The outer glass cylinder is called the "cover tube" and the inner one is called the "absorber tube".

(A) SOLARTECH ETC MODULE EVACUATED TUBE SYSTEMS - cont'd

1. Collector Module - cont'd

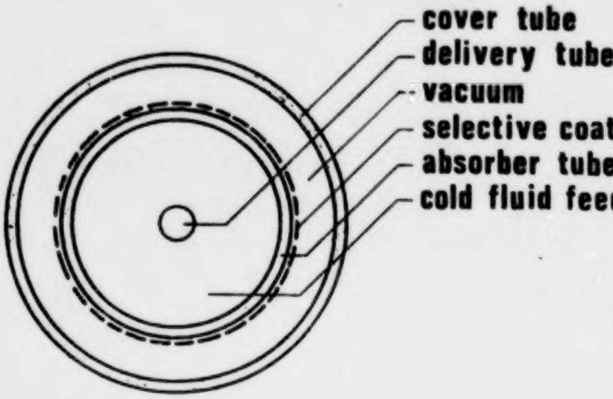
The absorber tube has a selective coating exposed to the side of the vacuum. Liquid flows upwards along the inside of the absorber tube and enters the stainless steel delivery (return) tube through an orifice at the top.

Collector feed and return manifolds are contained within an insulated jacket. Collector tubes are installed into the manifolds by friction fit (silicone rubber gasket and O-ring assembly) and held in place by a clamping device located at the top of the aperture.

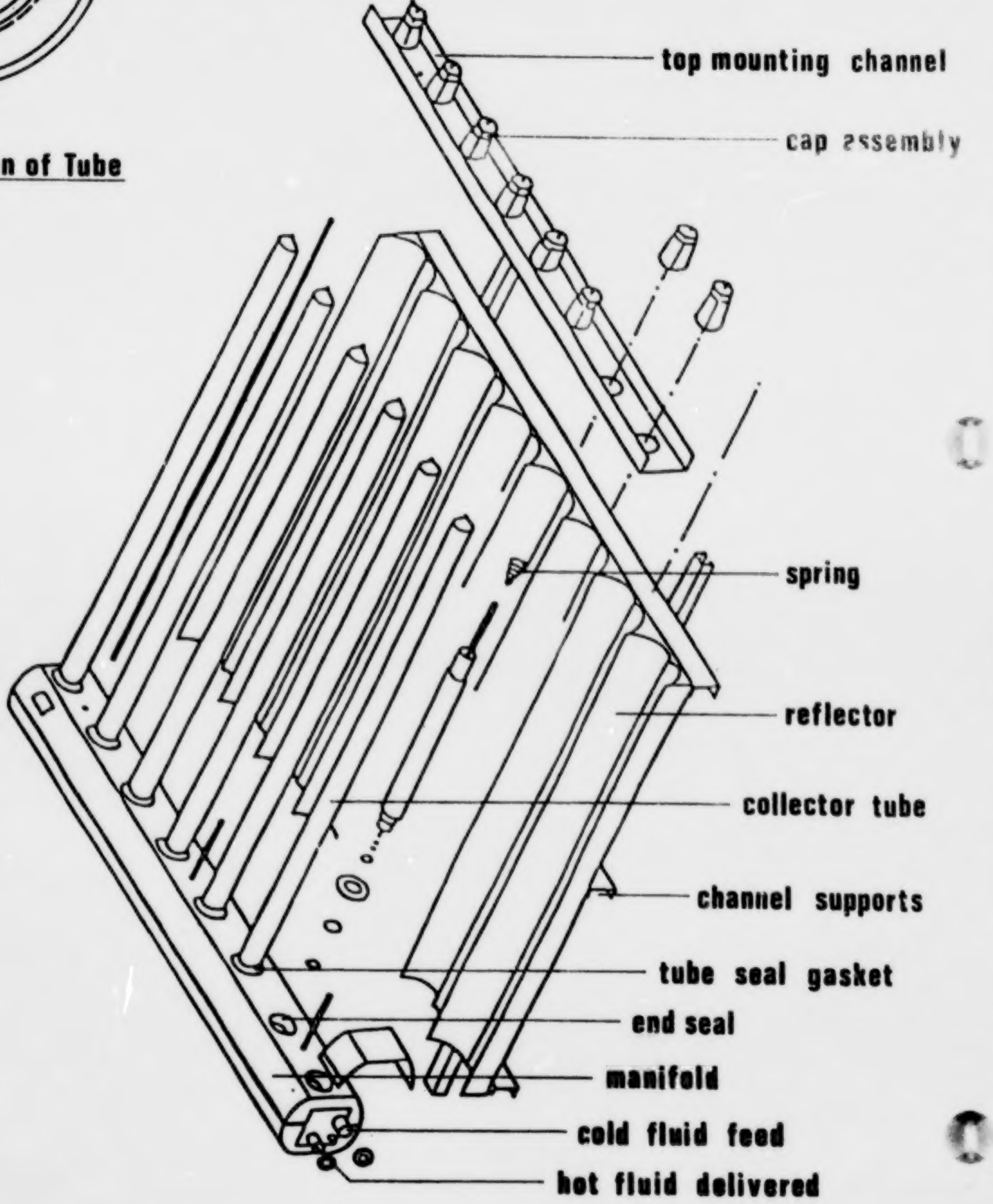
2. Operating Parameters

Nominal Flow (per module):	0.66 L/m
Max. Fluid Temperature (Receiver):	93°C
Maximum Operating Pressure:	35 kPa
Maximum Absorber Temperature to Prevent Thermal Shock on Cold Fill:	150°C
Approximate Fluid Temperature Rise: (Summer-Noon-Sunny Day at nominal flow)	20°C
Fluid:	Clean, filtered, softened water

SOLARTECH etc module



Cross Section of Tube



3. System Description

"SOLARTECH" evacuated tube modules are always circuited in a "drain-back" mode. The fluid used in the primary circuit is softened and filtered water.

A differential temperature controller energizes the primary pump upon a 17°C differential measured between the collector (with sensor located in special control tube) and the solar storage tank and de-energized the pump upon a differential of 4°C. To avoid excessive pump cycling the OFF-differential is overridden by a timer which ensures a 30 minute minimum pump run time after initiation by the ON-differential.

The primary pump is also locked out when:

(a) The collector high temperature sensor exceeds 150°C

and/or

(b) The water temperature in the Drain-back receiver exceeds 93°C.

Additional control and safety features pertaining to the primary and secondary circuit operation are outlined under "Instrumentation Guidelines".

Water is pumped from the drain-back receiver to the collectors and fed to individual vacuum tubes, all connected in parallel. Up to 12 collector modules may be connected to form one bank. Heated water returns to the drain-back receiver by gravity.

3. System Description - cont'd

A normally open solenoid valve opens when the primary pump stops. A system of vent piping connects the collector manifold outlets and the drain-back receiver to ensure proper drainage.

The drain-back receiver is vented to atmosphere or minimally pressurized by adding a relief valve set at 35 kPa and a check valve acting as vacuum breaker.

The pressurized system is preferred because less water is lost by evaporation and water treatment is simplified.

Most systems use copper for collector feed return and vent piping and a black steel tank as the drain-back receiver. Die-electric isolation must be used for joining dissimilar metals and a stringent program to control the water chemistry and purity of the primary circuit must be maintained with the Solartech evacuation tube system.

The configuration of the secondary circuit, storage tank and auxiliary heating is similar to that indicated for "Medium-to-Large Capacity Drainback Systems".

(A) SOLARTECH ETC MODULE EVACUATED TUBE SYSTEMS - cont'd

4. Special Considerations

1. Primary Circuit Flow Balancing

Improper flow distribution to individual collector tubes and to collector banks can cause damage to the tubes and the pipe circuitry due to freeze-up or thermal shock. The supply to each bank of collectors must be individually regulated by flow control valves. This flow rate must be maintained to the manufacturer's recommendations of 0.66 to 0.74 L/min. per collector. Each stainless steel delivery tube incorporates a small drilled orifice (approximately 1mm dia.) designed to offer a nominal pressure drop to ensure an equal distribution of flow between all evacuated tubes within the collector bank. The collector slope and the number of collectors per bank may affect the flow distribution between individual tubes.

Installations using 12 collectors per bank must be regarded as the practical maximum configuration. An uncoated evacuated tube is normally installed in the collector, located at the end of a bank (opposite supply and return connections) to permit a visual inspection of the fill and drain cycle.

(A) SOLARTECH ETC MODULE EVACUATED TUBE SYSTEMS - cont'd

4. Special Considerations - cont'd

1. Primary Circuit Flow Balancing - cont'd

If a filter-strainer is installed in the primary circuit, the pump must be sized to accommodate an increase in pressure drop due to progressive loading of the filter. If the pump is unable to deliver design flow to the collector banks, partial filling of tubes and improper circulation may result. This could lead to steam flashing, abnormal pressures, and thermal shock.

2. Primary Circuit Water Purity

Good water quality must be maintained to:

- Prevent calcium build-up and scaling within the vacuum tubes.
- Prevent galvanic corrosion and dissolution of the various metal piping and system components.
- Minimize the concentration of suspended particulates in the primary circuit.

Calcium build-up must be prevented to guarantee maximum collector efficiency; for this reason softened water is generally used.

4. Special Considerations - cont'd

2. Primary Circuit Water Purity - cont'd

Corrosion inhibitors and oxygen scavengers must be added to protect the metal components in the system in accordance with a program of chemical treatment designed by an approved chemical water treatment company. The absence of particulates is especially critical in evacuated tube collector systems because of the delicate balance which must be maintained between the small orifice in the stainless steel tube and the collector feed opening. Clogging of these holes can quickly result in thermal shock and frost damage.

Where an existing system does not include provisions for automatic flow control and/or reserve pump head, the water filter may be installed in the secondary loop where flow conditions are less critical or a sub-circuit can be installed, recirculating fluid in and out of the drain-back tank.

4. Special Considerations - cont'd

3. Steam Flashing in Tubes

The occurrence of steam flashing within collector tubes is not acceptable. Flashing can occur:-

- When no flow exists within a partially filled tube.
- When insufficient flow exists within a tube.
- On start-up when tubes are overheated.
- When collector supply water is excessively high and adequate pressure is not maintained.

On systems where precise flow distribution cannot be guaranteed (eg: where no automatic flow control devices exist or where variable flow is possible due to the gradual loading of the water filters), it is recommended that the tank high limit temperature setting be lowered to 80-85°C.

4. Collector Stagnation

While collector stagnation is permissible for empty collector tubes, it is important to ensure that hot tubes are not shocked with cooler system fluid. This is generally accomplished by installing a high limit temperature sensor inside a special collector tube, set at 150°C and wired to prevent primary pump operation.

5. Pump Control

The temperature differential controller starts the primary pump when a significant difference exists beteween the collector temperature and the solar storage tank temperature.

(A) SOLARTECH ETC MODULE EVACUATED TUBE SYSTEMS - cont'd

4. Special Considerations - cont'd

5. Pump Control - cont'd

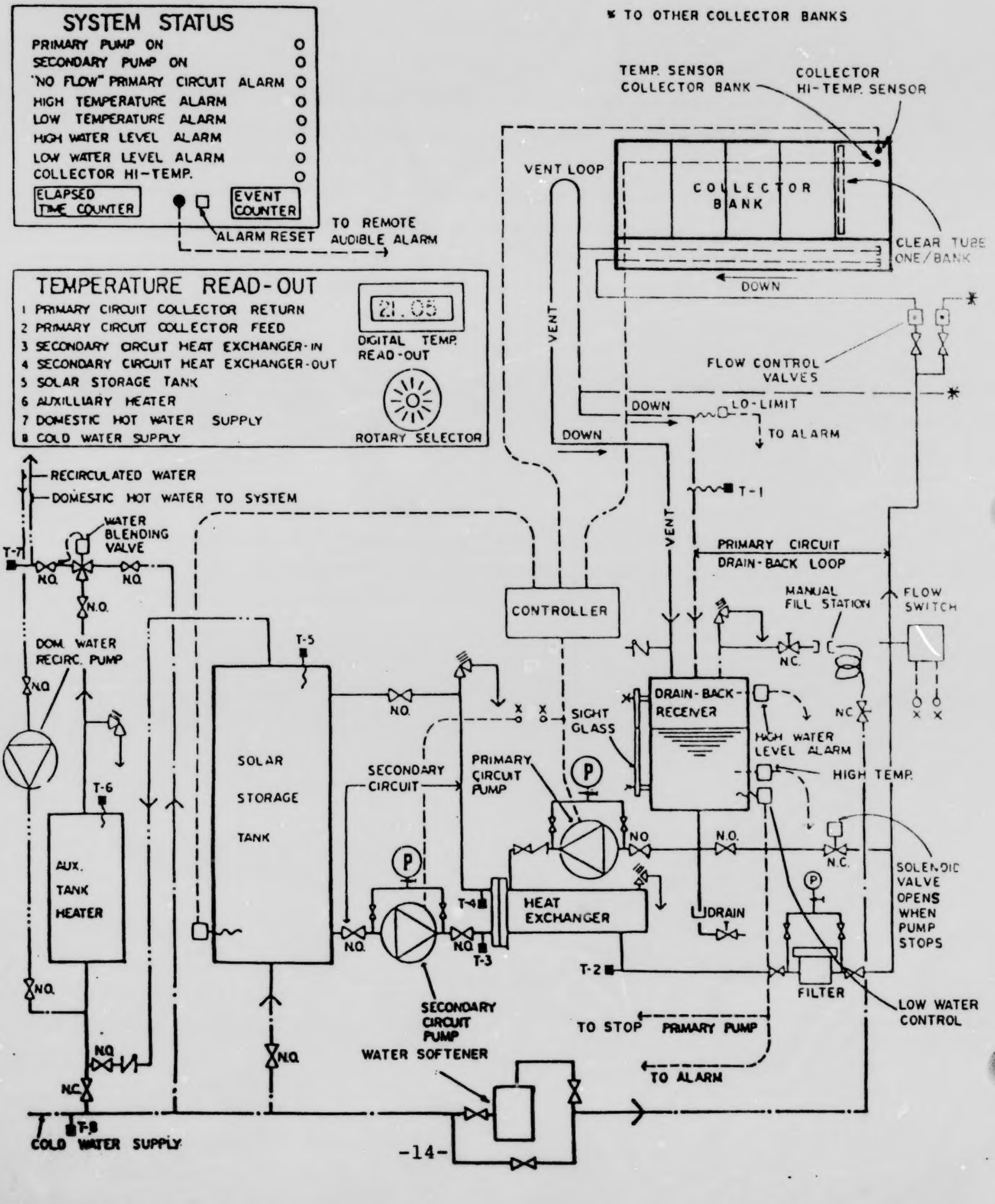
The system concept requires a much wider "ON" differential setting than standard flat plate systems in order to reduce frequent cycling. The timer ensures a minimum run time for each pump cycle, thus eliminating the possibility of controller "chatter". (Control chattering can cause partial filling of the system and subsequent freezing of exposed piping.) The system "OFF" differential setting is similar to that of other drain-back solar systems.

6. System Diagram

The following diagram entitled "EVACUATED TUBE - SOLARTECH DHW SYSTEMS" represents a typical system schematic and indicates suggested Control and Operational Monitoring Instrumentation.

EVACUATED TUBE - SOLARTECH

DOMESTIC HOT WATER SOLAR HEATING SYSTEM



(A) SOLARTECH ETC SYSTEMS - cont'd

6. Instrumentation Guideline

1. Temperature Indicators:

Temperature indicators are necessary for routine checks and to afford detection of abnormal operating conditions. Experience has shown that commercially available bimetallic or liquid-filled thermometers are of little use to the solar system operator. Such thermometers are usually out of calibration to a point where a comparison of fluid temperatures becomes meaningless.

Both the primary and secondary circuits have wide ranges in operating temperatures, eg: 5°C to 95°C. The relative temperatures, or temperature differentials, between circuit supplies and returns and the approach temperatures between primary and secondary circuits, however, are small in ETC solar heating systems:

- During maximum insolation, the temperature difference between collector feed and return in an evacuated tube system is usually 4°C to 17°C.
- The average difference on a sunny day between collector feed and return is 8°C to 10°C.
- The temperature differential between secondary circuit supply and return fluctuates between 0°C and 10°C.

and

- The approach temperature between primary circuit (collector loop) return and secondary circuit supply (leaving heat exchanger) usually fluctuates between 0°C and 17°C.

(A) SOLARTECH ETC SYSTEMS - cont'd

6. Instrumentation Guideline - cont'd

1. Temperature Indicators - cont'd

In addition to knowing the temperature levels of the primary/secondary circuits, it is the knowledge of the foregoing temperature differentials which indicates to the operator whether or not the solar heating system is operating correctly. Because temperature differentials within the primary and secondary loops are small (0-17°C) but may occur anywhere within the system operating range of 5-95°C, temperature sensors of exceptional accuracy and linearity are required to permit meaningful measurements. For a typical operating temperature differential of 8°C to 10°C, two measurements of plus or minus 0.5°C accuracy will produce a reading within 1°C, or 10% of the actual value. For the purpose of performance monitoring, this accuracy is considered a minimum standard.

2. Principle Types of Temperature Sensors

Reference should be made to the Phase II Manual concerning medium-to-large capacity drain-back systems for a detailed discussion of liquid-filled, bimetallic, thermocouple, thermistor, integrated circuit and platinum RTD temperature sensors.

3. Sensor Installation

It is recommended that all temperature sensors be installed in stainless steel thermometer wells located at piping tees in the solar system circuits to allow service, replacement and calibration procedures to be accomplished without loss of system fluid. Sensors should be installed in the wells with silicone thermal conductive compound to ensure accurate readings.

6. Instrumentation Guideline - cont'd

4. Provisions Made for Collector Bank Water Balancing And Performance Verification

Provisions should be made at each individual collector bank to allow measurement of the collector return temperature. The installation of automatic flow control valves on each collector bank supply is recommended. On a sunny day with the system operating, each collector bank should indicate the same temperature differential between feed and return. During operation, periodic checks should be made to verify that equal flow exists. It is recommended, therefore, that thermal wells or Peterson plugs be installed at the outlet of each collector bank, suitable for the insertion of a portable electronic probe. In addition, the installation of uncoated evacuated tubes (one per bank), permits visual inspection of the operational cycles.

5. Drain-Back Receiver High Temperature Alarm

There are several reasons why the drain-back receiver can reach abnormally high temperatures:

1. Over-collection of solar heat relative to domestic water load.
2. Secondary pump failing to operate in unison with primary pump; therefore solar heat collected cannot be transferred to the secondary circuit or to the domestic water.
3. Blockage or excessive fouling of heat exchanger tubes.

6. Instrumentation Guideline - cont'd

5. Drain-Back Receiver High Temperature Alarm - cont'd

A high limit temperature sensor installed in the drain- back receiver shall cycle the primary circuit pump 'off' whenever temperature in excess of 93°C are experienced. A visual alarm should indicate the high temperature conditions.

6. Collector High Temperature Alarm

The sensor, which is installed in a special control tube, will not permit primary pump operation when the collector tube temperatures exceed 150°C. This state should be indicated visually by an alarm light.

7. Cycle Control Timer

This timer ensures a minimum system run time after initial start-up of primary pump.

8. Pressure Gauges

A pressure gauge through switchover valves should be installed across the primary circuit pump, capable of measuring pump suction or discharge pressure. In a case where the primary system is vented to atmosphere, the pressure gauge will read between 10 and 20 kPa when the pump is off (pressure equivalent to water column measured vertically between gauge and water level in receiver).

6. Instrumentation Guideline - cont'd

8. Pressure Gauges - cont'd

Where a pressurized loop is adopted (as shown on the system diagram), the pressure gauge will read anywhere between 0 kPa and the relief valve pressure setting, depending upon the elevation of pump, water level and pressurization. Upon start-up, as the collector feed line fills with water, the discharge pressure will increase gradually to overcome the static head of the system and the pressure differential imposed by the flow control valves.

9. Primary Circuit Flow Switch

When the primary circuit pump is operating, flow should exist through the primary loop. If, for any reason, the pump is not capable of developing discharge pressure sufficient to sustain circulation, the solar system is rendered entirely ineffective.

It is recommended that a flow switch be installed in the primary circuit, wired to the system status panel to annunciate a no-flow condition. The alarm would be wired so as to be effective only if a no-flow condition occurs while the primary pump is running.

10. Low Water Level Alarm

A low water level could occur due to:
- Natural evaporation of primary circuit fluid.
- Leak in circuit piping or collectors.
- Frozen or broken evacuated collector tubes.

A low water condition can result in primary circuit pump cavitation and pump over-heating, leading to ineffective operation and potential material damage.

(A) SOLARTECH ETC SYSTEMS - cont'd

6. Instrumentation Guideline - cont'd

10. Low Water Level Alarm - cont'd

It is recommended that a low water level probe be installed in the drain-back receiver, wired to sound an alarm whenever a low water level occurs in the drain-back tank.

11. High Water Level Alarm

A high water level could occur due to:

- Overfilling of primary circuit system
- Cross-contamination between secondary and primary circuits.

A high water condition can result in restricted venting of the drain-back lines and collectors. This problem could lead to residual water remaining in the primary loop when the pumps are off, causing system inefficiency and possible freeze-up of the collectors and lines during cold weather.

A high water level probe should be installed in the drain-back receiver to give an audible and visual alarm whenever excessive water levels are encountered.

Provision should be made to protect the high-level detector probe from nuisance alarms or damage by properly designing the inlet configuration connecting the return line to the drain-back receiver.

(A) SOLARTECH ETC SYSTEMS - cont'd

6. Instrumentation Guideline - cont'd

12. Elapsed Time Indicator - Secondary Circuit Pump

The provision of an elapsed time meter showing accumulated run time of the secondary circuit pump will give the operator a reasonable indication of the solar system performance. Control system problems, and especially abnormal continuous operation with resulting energy waste, may be detected by regular observation of run time.

The secondary circuit pump should be wired through the flow switch installed in the primary circuit. Whenever flow exists in the primary circuit, the secondary circuit pump will operate.

13. Event Counter

The event counter is an electro-mechanical device indicating the number of secondary circuit pump on-off cycles. This relatively inexpensive device would be very useful to initially set up the temperature differential settings activating and de-activating the circulating pumps. In addition, the event counter could be useful in detecting abnormal and erratic cycling due to intermittent wiring connections, controller or sensor problems, or timer failure.

(A) SOLARTECH ETC SYSTEMS - cont'd

6. Instrumentation Guideline - cont'd

14. Freeze Protection

Automatic frost protection must be considered for the primary circuit. The frost protection thermostat should be installed in the collector return line and wired to stop the primary circuit pump in the event that fluid temperatures below 5°C are encountered. This switch must be wired to override the timer. Low temperature alarm annunciation should be incorporated at the system status panel.

7. Operational Monitoring and Maintenance Procedures

The type and extent of instrumentation provided for operational monitoring is considered to be that necessary to furnish the operator with sufficient information to make routine diagnoses, to calibrate and adjust the controls, and to ensure annunciation of alarm conditions.

The "Operator's Check List" should be used to record operating conditions and to perform operational analyses. Certain modifications and amendments may be required to the check list in order to suit the actual system design concept. The frequency of use depends upon the complexity and performance record of the solar system.

The "Maintenance Schedule" separates the system into components and lists the recommended procedures and frequency of each maintenance task. This schedule may have to be expanded or altered in order to accommodate other design concepts or specific manufacturer's recommendations.

7. Operational Monitoring and Maintenance Procedures-cont'd

The Operational Problems Chart serves as an aid to system trouble-shooting.

The use of the "Operator's Check List" may help in the detection of operational problems. The "Operator's Guidelines" reflects system concepts illustrated in this manual and explains the operation of individual control and monitoring components. It will help the operator to properly control and monitor the system, to identify problems, and to perform the necessary corrective measures.

OPERATOR'S CHECK LIST

EVACUATED TUBE DRAIN-BACK SOLAR WATER HEATING SYSTEM

PROJECT: SYSTEM MANUFACTURER:

OPERATOR: MONTH: YEAR:

Date and Time	Weather (Check One)			Approx. Outdoor Temp. °C	Power On Yes or No	Pumps On		Temperatures (°C)								System Press. kPa Pr.Cct	Elapsed Time Hours & Tenths of Hours	Interval Counter Total Counts	System Alarms					Overflow Containers (Wet/Dry)		Water Added Yes or No	Visible Leaks Yes or No
								Heat Exchangers				Storage Tanks		Water Supply					High. Limit Yes or No	Low Limit Yes or No	Liquid Level Yes or No		No Flow Yes or No	Clos. Loop	Solar Stor-age Tank		
								Primary		Secondary																	
	SUNNY	PARTLY SUNNY	CLOUDY NO SUN			Primary	Secondary	IN T-1	OUT T-2	IN T-3	OUT T-4	Solar T-5	Aux. T-6	Hot T-7	Cold T-8						Hi	Lo					

MAINTENANCE SCHEDULE - SOLARTECH EVACUATED TUBE SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
Complete System	Operational Checklist	x	x	x	X	x	Initially more frequently, then as required.
COLLECTORS:							
Tubes	Inspect for leaks, breakage, overheating tubes. Tubes should feel cool on sunny days. Replace if hot		x				Barium getter within tube may turn white if vacuum is lost
	Check fill/drain cycle at uncoated tubes		x				
	Manage snow		x				Winter months only
	Wash externally with warm soapy water					x	Including reflector, more often if dirty
	Descale with dilute acetic acid. Rinse					x	If internal scaling is evident
Supports/Mounting and Fasteners	Check structure, tighten bolts, inspect isolation pads, touch-up where corrosion is evident					x	
Piping	Inspect hangers and supports. Adjust, check pipe slopes					x	Resupport pipes if sagging
	Measure drain-back time.				x		Particularly important before winter season
	Check flow balancing for each collector array. Complete balancing procedures are outlined in the Solar Programs Office Commissioning and Monitoring Procedures Documents					x	Temperature at inlet/outlet of each array can be measured with calibrated electric thermometer near noon on a sunny day (with system running)

MAINTENANCE SCHEDULE - SOLARTECH EVACUATED TUBE SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
COLLECTORS: (cont'd)							
Piping (cont'd)	Verify pipe jackets and insulation. Repair weatherproof jackets where necessary. Replace wet fibreglass insulation. Inspect for UV degradation of plastic pipe jackets.					x	
	Check pipe connections and roof penetrations					x	Use 95-5 solder for copper pipe repairs
Control Modules	Verify wiring/connections and mounting of sensors				x		
DRAIN-BACK RECEIVER	Check water levels. Replenish with softened treated water			x			Also upon alarm signals
	Clean, descale, remove sediment and flush					x	Including probes
	Inspect tank insulation				x		
Level Sensors	Check and clean sensors. Operate manually					x	
PUMPS AND MOTOR CONTROLS							
Motors	Check amps, temperature, RPM					x	
Contactors and Switches	Inspect and torque connections. Check for pitting; replace points					x	
Bearings	Listen for vibration/noise. Lubricate				x		Where applicable

MAINTENANCE SCHEDULE - SOLARTECH EVACUATED TUBE SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
FUMPS AND MOTOR CONTROLS (cont'd)							
Seals	Check carbon/ceramic, O-ring and mechanical seals for noise, wear and leakage.			x			As per manufacturer's recommendations. Replace if leaking
Couplings	Inspect for play. Tighten if loose			x			
Mounting and Alignment	Verify. Adjust if required					x	
Impellers	Listen for noise. Measure developed pressure				x		
HEAT EXCHANGER	Measure & record pressure drop through convertor			x			
	Clean and inspect units as per manufacturer's recommendations. Service if pressure drop exceeds initial value by 20%.					x	Shell & Tube Exchangers: If floating heads, rod-through tubes. If bundle type use chemical cleaning & flushing. If plate type, disassemble and clean using fibre brush with soda ash/detergent solutions.
	Replace gaskets						As necessary.
STORAGE TANKS	Inspect tank insulation					x	
	Inspect linings for cracking, deformation or melting. Storage tank lining to be identified & labelled.					x	Repairs should be performed as per manufacturer's recommendations. Different tanks have significantly different maximum temperature limitations and repair & maintenance requirements.

MAINTENANCE SCHEDULE - SOLARTECH EVACUATED TUBE SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
STORAGE TANKS (cont'd)							
	Typical linings for tanks include directly applied cement (sometimes referred to as 'stone-lined'), cement applied to welded mesh, calcium aluminate coatings (eg: "Alcrete"), skin-tight copper linings, epoxy finishes and vinyl plastic sheet inserts.						All can benefit from frequent flushing and cleaning.
	Verify condition of magnesium anodes and other corrosion protection devices.					x	Where installed.
Cement Lined	Drain, open manhole, carefully inspect lining. Patch with material/method recommended by manufacturer. Remove debris, flush, replace gasket if necessary and refill.					x	During winter months, preferably on cloudy day. Provide adequate lighting and ventilation.
Glass Lined	Inspect. Repair/replace as per manufacturer's recommendations					x	Required only if blocked or if corrosion evident in water supply can be traced to tank.
Plastic (Vinyl or Epoxy)	Inspect for damage, leaks or discolouration. Drain, remove debris then flush. Repair as per manufacturer's recommendations.					x	Water should not penetrate behind these liners.
Probes & Sensors	Disconnect, clean and manually test if possible					x	Well-mounted units can be accessed externally.

MAINTENANCE SCHEDULE - SOLARTECH EVACUATED TUBE SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
PIPING ACCESSORIES							
Primary and Secondary Loops	Verify mounting, hangers and slopes. Check for leaks and damaged or wet insulation					x	Repair as required
Valves	Manually operate. Check for stem leaks etc. Inspect glands and seals. Verify that they are returned to balanced or normal (NO/NC) operating positions					x	Replace if necessary. Valves should have tags attached, stating their function & normal setting
Check Valves/ Vacuum Breakers	Open, clean and verify operation where possible. Check springs on spring-operated valves.					x	
Strainers	Open, remove basket, clean and flush			x		x	More frequently if indicated by excessive pressure drop, and during start-up
Water Filters	Monitor pressure drop.			x			Replace media/cartridge as required.
Relief Valves	Inspect if outlet port & discharge pipe are clear. Manually operate levered type. Verify setting if adjustable.					x	Replace overflow container under outlet pipe (if present).
Air Vents	Ensure floats and seals are clean on serviceable units. Check that vent caps are loosely screwed on. Inspect for leaks.				x		

MAINTENANCE SCHEDULE - SOLARTECH EVACUATED TUBE SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
PIPING ACCESSORIES (cont'd)							
Fluids	Check level, top-up with filtered softened water.			x			More often if necessary
	Inspect for presence of colour or suspended solids.			x			
	Conduct program of chemical tests and treatment as formulated for the particular solar system and local water conditions.		x				Or as directed by water treatment company. Fluid may have to be completely replaced every few years, depending upon the water quality and the behaviour of the solar system.
CONTROLS AND MONITORING INSTRUMENTATION							
Differential Controller	Verify correct system status indications for "OFF", "MANUAL" & "AUTOMATIC" control positions. Check that pumps are actually running per control indications.			x			
	Turn power off, then reset to verify controller start-up operation.			x			Preferably on sunny day.
	Measure and adjust controller "ON" and "OFF" temperature differentials					x	Certain controllers give direct electronic or digital readouts; others will require the placement of sensors in temperature baths to fully verify set points

MAINTENANCE SCHEDULE - SOLARTECH EVACUATED TUBE SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
CONTROLS AND MONITORING INSTRUMENTATION (cont'd)							
System Status Panel	Operate and reset all alarm and status-indication circuits (high water, low water, high temperature, low temperature etc.)				x		
	Check elapsed time meter & event counter for proper operation.			x			
Temperature Readout Panel	Record temperatures at all sensing points and verify (T-collector out T-collector in etc.)		x				Pumps must be circulating for several minutes before readings are taken.
	Withdraw sensors from wells and check as-installed calibration at ice-point & boiling point of water					x	Required at least once during lifetime of a system & more often if system uses sensors other than platinum RTD units.
Wiring (Power)	Check insulation near controllers, contactors & motors for signs of shrinking or brittleness. Inspect for physical damage of wire or conduit					x	Overheating of wire may be due to poor relay contacts, loose terminals or overloaded pump motor; check.
Wiring (Sensors)	Verify that junctions, protective conduits and shielding are intact. Loosen off and retighten terminal screws.					x	

OPERATIONAL PROBLEMS

SOURCE OF PROBLEM	POSSIBLE CAUSES	CONSEQUENCES	PERFORMANCE MONITORING
PUMP: Failure to operate when required to.	- Power off, Blown Fuse or Tripped Breaker - Not started through controller - Motor burned out - Impeller seized, blocked or disconnected. - Electrical Problem - Open cct.in collector sensor wiring - Short cct.in storage tank sensor wiring. - Control System Problems	- No collection of solar heat	Observation of Elapsed Time Indicator Observation of Event Counter Observation of Temperatures No-flow condition-alarm (flow switch)
PUMP: Operating when not required to:	- Control set to Manual Op. - Problem with sensors and/or controller - Faulty Switch - Faulty Wiring - Closed cct.in collector sensor wiring - Open cct.in storage tank sensor wiring - Control System Problems	- Reverse heat exchange - Freeze-up of collectors & primary circuit piping	Low Temperature Alarm Frost Protection Thermostat to shut down pump Observation of Elapsed Time Indicator Observation of Event Counter Observation of Temperatures
CONTROLLER: Not operating correctly	- Not adjusted correctly - Sensors loose - Faulty wiring - Faulty electronics - Faulty switches	- Inefficiency - Steam formation in collectors - Freeze-up of collectors and exposed piping. - Thermal shocking of tubes	High Temperature Pump Cut-off & alarm Low Temperature Alarm & Pump Cut-off Observation of Elapsed Time Indicator Observation of Event Counter Observation of Temperatures
NO CIRCULATION Pump Running	- Improper Venting - Low water level in receiver - Leak in piping system (fluid lost) - Part of piping system frozen up - Blockage in piping system - Impeller or drive defective	- No collection of solar heat - Pump cavitating - Pump overheating	No-flow Condition-alarm (flow switch) Observation of Temperatures Observation of Pressure Gauges Low water level alarm

OPERATIONAL PROBLEMS

SOURCE OF PROBLEM	POSSIBLE CAUSES	CONSEQUENCES	PERFORMANCE MONITORING
LEAK IN PIPING SYSTEM	- Incorrect solder joints - Expansion/contraction causing break - Frost Damage - Corrosion - Broken evacuated tube - Tube improperly seated	- Loss of primary circuit fluid - No collection of solar heat - Poor or no water circulation - Pump Overheating	Low Water Level Alarm High Temperature Alarm Observation of Pressure Gauges Observation of Temperatures
FROST DAMAGE TO PRIMARY CIRCUIT	- Improper venting - Improper slopes of pipes and collector banks - Faulty controller, sensors, connection and wiring.	- No flow - Break in piping circuit - Loss of fluid	Frost protection thermostat to shut down pump and alarm
CROSS CONTAMINATION (for systems with direct heat exchanger)	- Leak in heat exchanger	- Primary circuit fluid transferred to domestic water circuit. - Dom.water transferred to primary circuit, followed by venting problems and possible freeze-up of primary loop	Low Water Level Alarm Observation of sight glass on drain-back tank. High Water Level Alarm
VENTING/DRAINAGE	- Improper slopes - Pipe buckling - Overfilling of drain-back receiver - Pipe blockage or constriction - Partial freeze-up	- Inefficiency - Freeze-up of collectors and piping	Observation of fill and drain-back cycle through sight glass is a partial solution; proper design of slopes and venting remains the primary consideration

OPERATOR'S GUIDELINES

1. SUNNY CONDITIONS AND PARTLY SUNNY CONDITIONS

The solar system should be cycling.

2. CLOUDY OR NO SUN CONDITIONS

The solar system may cycle only if the ambient outdoor temperature is sufficiently higher than the incoming water temperature or the temperature existing at the bottom of the solar storage tank.

3. PCWER

If solar system does not perform as described under the above weather conditions, check main and branch circuit breakers.

4. PUMPS

1. Primary Circuit Pump

Primary circuit pump is activated and de-activated through differential temperature controller and should cycle as described under paragraphs 1 and 2. If NOT, check power connection, starter relay and wiring

- Differential controller setting
- Control sensor connections and transmission
- Controller
- High limit cut-out.
- Low limit freeze protection

OPERATOR'S GUIDELINES

4. PUMPS - cont'd

2. Secondary Circuit Pump

This pump should always run when the secondary circuit pump is operating and flow is present in the primary circuit.

If this is not the case, check:
- that all valves are open in primary circuit
- flow switch and control wiring
- Secondary circuit pump starter, relay power wiring and motor
- Primary circuit flow. If no flow, check pump motor, coupler and impeller.
- Physical blockage in heat exchanger or pipes of primary circuit.

5. ELAPSED TIME METER

- On a sunny day, the system should always have some run time. The number of hours that the system (pump) runs depends on:

(a) How much domestic hot water is drawn
(b) Hours of sunshine
(c) Time of year
(d) Outside temperature

The system may also run (cycle) on cloudy days or at night provided that the domestic water temperature entering the solar tank is much colder than the outdoor ambient temperature. Such run time, however, should be minimal. If the elapsed time meter shows excessive running (eg: more than 10 hours on a sunny day), a control problem may exist. Check if temperature sensors have come loose at collector or at storage tank.

5. ELAPSED TIME METER - cont'd

- If elapsed time meter shows no operation during sunny periods, check whether:

  (a) Temperature sensors have come loose or detached at collector or storage tank.

  (b) Freeze temperature setting is incorrect.

  (c) System is off on "freeze".

  (d) System is off on high-limit.

6. EVENT COUNTER

This instrument is useful to detect excessive cycling of pumps or the absence of cycling.

Excessive cycling may indicate:

- Control system temperature differential settings too close
- Control system problems
- Intermittent wiring connections
- Flow set too high

Absence of, or very infrequent cycling may indicate:

- Control system temperature differential settings too wide.
- Control system problems
- Open or shorted temperature sensors.
- Restricted flow

7. CIRCUIT TEMPERATURES

Refer to "Evacuated Tube System" diagram on page 14.

- T-1 temperature should always be higher than T-2.
- The temperature differential should not exceed 18-20°C maximum insolation. If higher temperature differentials exist, and the loop operates at a reduced flow rate, check for:
  - partially closed valves
  - dirty strainer
  - blockage
  - air lock
  - pump problems
- During sunshine periods with pump operating, a small temperature differential should always exist. If this is not the case, check:
  - valves closed in collector loop
  - No-flow for any reason
  - snow covered collectors
  - pump/impeller disengaged
  - freeze-up of collector loop

T-1 and T-2 temperature levels will fluctuate between 5°C and 95°C. Elevated temperature levels indicate large reserves of solar heated water. Without domestic water consumption, overcollection will result. This would lead to excessive loop temperature and pressure, and subsequent discharge of fluid through primary and/or secondary circuit relief valves.

7. CIRCUIT TEMPERATURES - cont'd

While the secondary pump operates, T-4 temperature should always be higher than T-3 temperature. If this is not the case, there may be no-flow through the secondary circuit, or a control system problem may exist leading to reverse heat exchange.

T-4 temperature should always read lower than T-1 whenever the pumps are operating.

Temperatures 1, 2, 3, 8 and possibly 5, may read near room temperature during periods when no flow exists through these circuits.

T-5 will read the temperature of the stored water. This temperature usually varies between 5°C (high domestic water draw without solar energy collection) and approximately 80°C (little or no domestic water drawn in combination with maximum solar energy collection).

T-6 will read the temperature of the domestic water in the auxiliary heating tank; normally set between 50°C and 80°C.

T-7 is the domestic hot water supply temperature, normally maintained between 45°C and 70°C.

T-8 reads incoming cold water temperature.

8. PRESSURE GAUGE PRIMARY CIRCUIT

The gauge reading the pump discharge pressure will indicate build-up of static head as the collector feed lines are filled with water. Upon resumption of normal circulation the discharge pressure will reduce as the collector return lines fill with water and syphon action is encountered.

The suction pressure, with atmospherically vented systems, will be near 0 kPa while the pump is in operation. When the pump is off, the gauge will read the pressure of the static head (water column measured vertically between the water level in the drain-back tank and the pressure gauge).

With "semi-closed" loop designs, both the suction and discharge pressures are elevated by the amount of pressurization at a given time.

9. PRESSURE GAUGE SECONDARY CIRCUIT

The pressure gauge on the secondary pump will fluctuate with the city water pressure and is used to observe pump performance.

10. FREEZE PROTECTION THERMOSTAT

This instrument should be set at 5°C; it protects the primary circuit from frost damage, stops the primary circuit pump, and sounds an alarm.

OPERATOR'S GUIDELINES

11. HIGH TEMPERATURE LIMIT THERMOSTAT

The high limit thermostat should be set to sound an alarm at temperatures in excess of 90°C; causes for which could be:

- Over-collection of solar heat relative to DHW consumption.
- No flow in secondary circuit.
- Blown or tripped circuit breaker of secondary pumps
- N.O. valves in secondary circuit in closed position.
- Heat exchanger problems.

12. LOW WATER LEVEL

Water must be added periodically to the primary circuit to make up for evaporative losses.

If the system is shut down frequently upon low water level condition, check for:

- Leaks in primary circuit
- High temperature limit setting too high (steam may be formed in collectors)
- Cross-contamination, primary circuit leaking water through convertor to secondary circuit (possible with semi-closed loop design only).

13. HIGH WATER LEVEL

A high-level water condition in the drain-back receiver may render the venting system ineffective. This situation could arise from overfilling of the primary loop or leakage through the heat exchanger from the domestic water side. The high-water level alarm would annunciate such a condition. Corrective action must be taken immediately.

14. CALIBRATION OF SENSORS

Calibration of all temperature sensors in their "as-installed" configuration can permit a system operator to monitor and maintain a solar domestic hot water circuit with significantly increased efficiency, accuracy and confidence. A simple calibration procedure using readily available materials may be performed at the ice-point of water (0.0°C) and at the boiling point of water (100°C), depending upon the atmospheric pressure:

> Crushed or broken ice is placed in a wide-mouth thermos containing cold water and the mixture is allowed to equilibrate. As long as significant quantities of both ice and water are present, the temperature of this mixture rapidly reaches 0.0°C (plus or minus 0.1°C) and is little affected by the local temperature or atmospheric pressure. One by one the temperature monitoring probes are withdrawn from their wells and placed in the thermos (near their original place of installation) and, after a settling period, the temperature is read at the central indicator unit.
>
> If 'zero' adjustment is possible, then each sensor channel is set to read 0.0°C while its corresponding probe is in the ice water bath; otherwise, a note of the observed error at 0°C (eg: T1 is 0.3° high, T2 is 0.5° low, etc) is made and clearly posted.

The same basic method is employed for the 100°C point except that water boiling vigorously on a hot plate is used and correction should be made for the atmospheric pressure.

14. CALIBRATION OF SENSORS - cont'd

The 'standard atmospheric' pressure is 101.3 kPa; the boiling point of water decreases approximately 0.3°C for each kPa reduction in pressure and increases 0.3°C for each kPa increase in pressure. At a local pressure of 100 KPa, therefore, water can be expected to boil around 99.6°C. The actual boiling point is thus determined and the sensor instrument error is adjusted or recorded as required.

(B) SOL PRO E-100 EVACUATED TUBE SYSTEM

1. Collector Module

The Sol-Pro E-100 Module is a product formerly marketed by Amherst Renewable Energies Ltd (Model VTR 261). The evacuated tubes are manufactured by Philips, Holland.

Three modules are available:

8 tube design with gross area of 1.5m^2
10 tube design with gross area of 1.85m^2
12 tube design with gross area of 2.2m^2

The evacuated glass tube encloses a finned, selectively coated, copper absorber which, in turn, is mechanically bonded to a heat pipe running the full length of the tube. The heat pipe contains a hydro-carbon liquid under a partial vacuum.

Heat is conveyed to an integrated heat exchanger/condenser assembly which is clamped onto a header pipe. Heat exchange takes place whenever the liquid contained in the heat pipe boils as a result of solar energy captured by the surrounding absorber plate.

The vapour rises to the top of the tube and condenses on the cooler metal clamp assembly as heat is transferred to the primary loop fluid flowing through the header. The tubes are individually attached to the header with four bolts, using high temperature heat conductive grease. Since no system fluid flows through the collector tubes, individual tube replacement is possible without affecting the operation of the hydronic system.

No degradation of the selective absorber surface is anticipated since the absorber is located in the vacuum.

1. Collector Module - cont'd

Up to 40 collector modules can be connected in series. The primary system can be a "closed loop" concept containing an anti-freeze or a "drain-back" concept using water. Two condenser pipe/clamp sizes are available; the large size (25.4mm) is usually used for multiple collector installations.

The following system descriptions assume the application of a "closed loop" system for domestic water heating, with primary loop temperatures not exceeding 95°C.

The Sol-Pro modules are suitable for water heating systems exceeding 100°C, however the system configuration requires additional considerations adopting "high temperature water" design standards. If the Sol-Pro modules are used in a drain-back loop, reference can be made to the Phase II Manual entitled "Medium-to-Large Capacity Drain-Back Systems".

2. System Description

Closed loop domestic water heating systems using the Sol-Pro evacuated tube collectors are designed similarly to those described in the Phase I and II Closed Loop system manuals. The main differences are:

1. Reduced flow rate per collector module.
2. Higher inlet-outlet temperature differentials.
3. Wider "ON" setpoints for the differential controller. (typically 15-20°C).
4. Necessity of a timer to prevent unwanted pump cycling on large systems.

(B) SOL PRO E-100 EVACUATED TUBE SYSTEM - cont'd

2. System Description - cont'd

5. On packaged systems, timer control is used instead of differential temperature control as follows:
   The 24 hour quartz-driven electro-mechanical timer has a summer-winter setting. In the summer the pump operates continuously for 12 hours (6:00 to 18:00). In winter the pump runs for 8 hours (8:00 to 16:00). A 72-hour battery power backup is provided in case of a power failure.

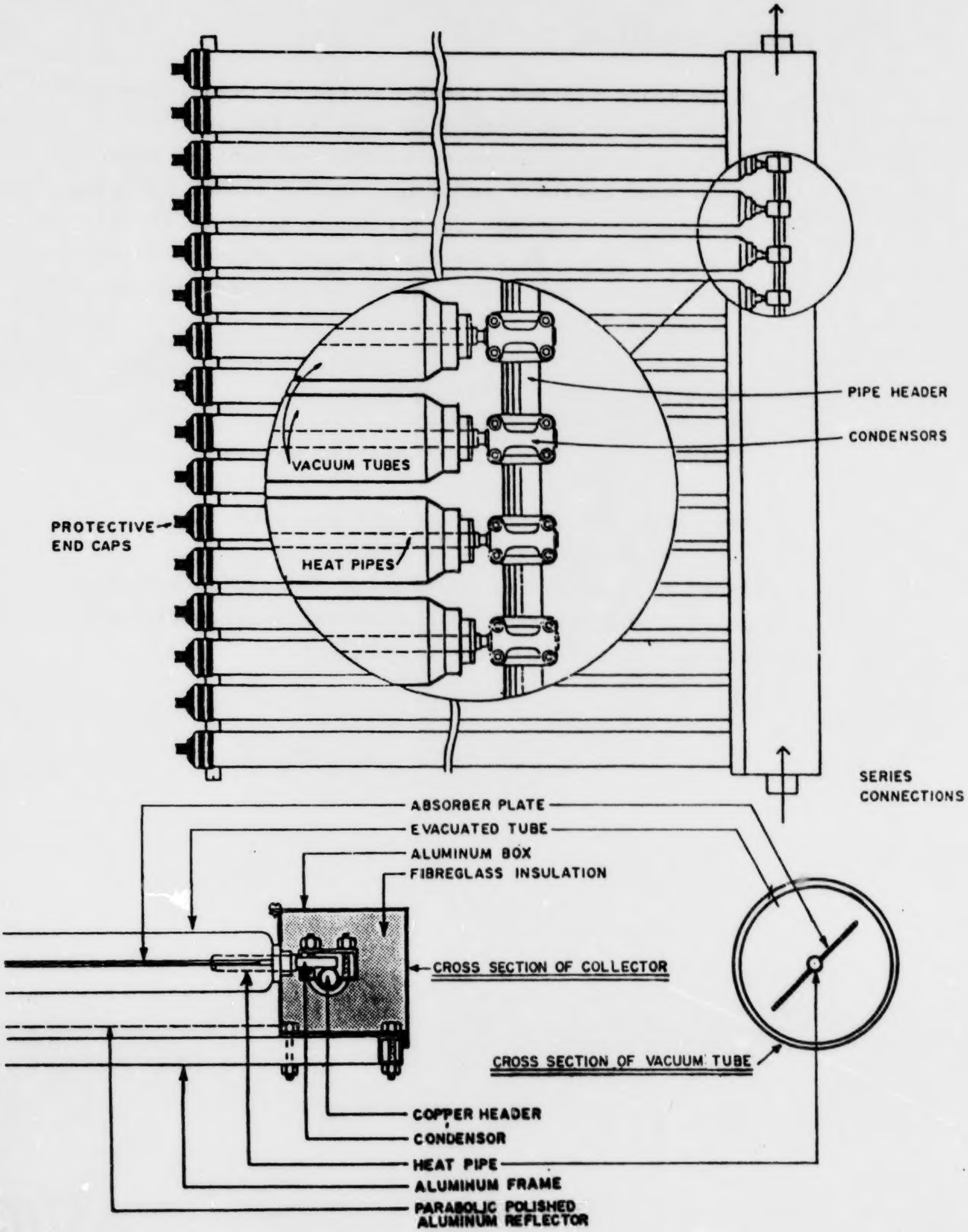
3. The following diagrams entitled:

"Evacuated Tube - Sol-Pro"
"Domestic Hot Water Solar Heating System"
and
"Packaged Closed Loop Domestic Hot Water Solar Heating System - Sol-Pro"

represent typical system schematics and indicate suggested control and operational monitoring instrumentation pertaining to a closed loop configuration.

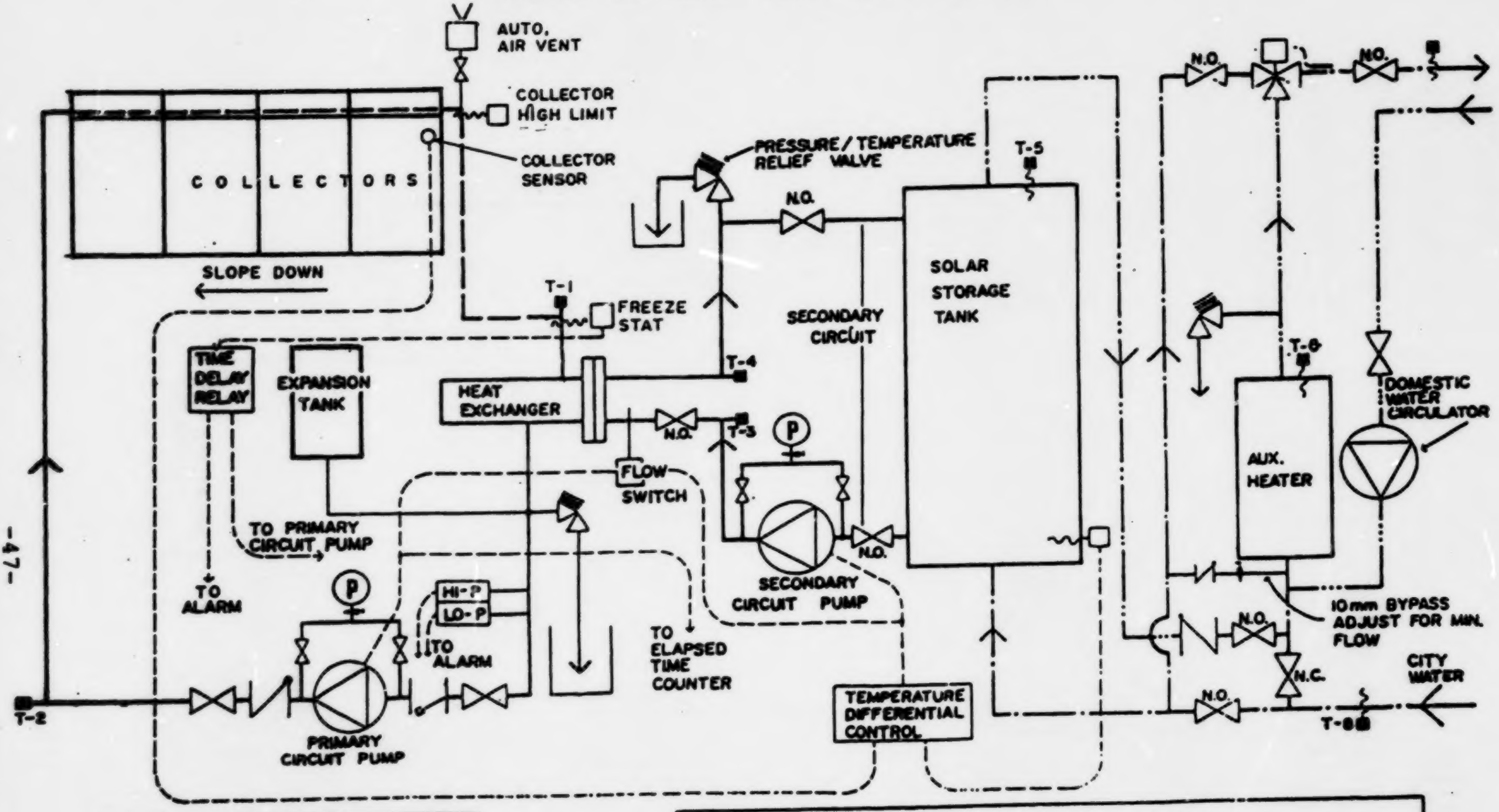
EVACUATED TUBE Sol-Pro

(philips vtr 141,261 etc)



EVACUATED T E sol - pro

DOMESTIC HOT WATER SOLAR HEATING SYSTEM



SYSTEM STATUS

- PRIMARY PUMP ON ○
- SECONDARY PUMP ON ○
- COLLECTOR HIGH-TEMP. ALARM ○
- LOW LIMIT ALARM ○
- LOW PRESSURE ALARM ○
- HIGH PRESSURE ALARM ○
- ALARM RESET
- ELAPSED TIME COUNTER
- EVENT COUNTER

TO REMOTE AUDIBLE ALARM

TEMPERATURE READ-OUT

1 PRIMARY CIRCUIT COLLECTOR RETURN
2 PRIMARY CIRCUIT COLLECTOR FEED
3 SECONDARY CIRCUIT HEAT EXCHANGER - IN
4 SECONDARY CIRCUIT HEAT EXCHANGER - OUT
5 SOLAR STORAGE TANK
6 AUXILLIARY HEATER
7 DOMESTIC HOT WATER SUPPLY
8 COLD WATER SUPPLY

21.05

DIGITAL TEMP. READ-OUT

ROTARY SELECTOR

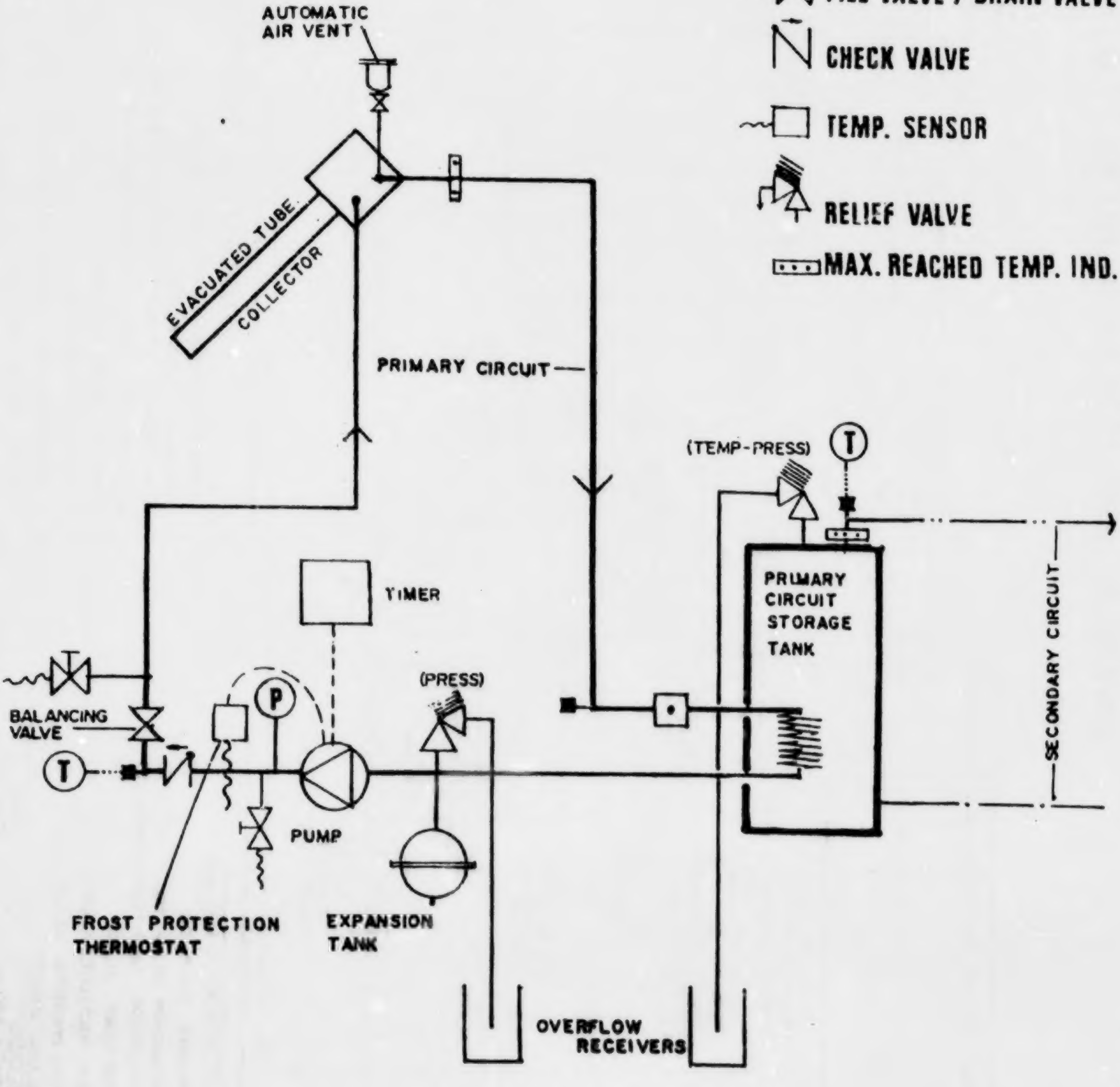
PACKAGED

CLOSED LOOP

DOMESTIC HOT WATER SOLAR HEATING SYSTEM

Sol- Pro

- Ⓣ THERMOMETER
- ■ PETERSON PLUG
- Ⓟ PRESSURE GAUGE
- ⊡ FLOW INDICATOR
- ⋈ VALVE
- FILL VALVE / DRAIN VALVE
- CHECK VALVE
- TEMP. SENSOR
- RELIEF VALVE
- MAX. REACHED TEMP. IND.



(B) SOL PRO E-100 EVACUATED TUBE SYSTEM - cont'd

4. Operating Parameters (Medium-to-Large Capacity Systems)

Nominal Flow:	1.0 L/min. per collector module when multiple collectors are installed in series with 25.4mm pipe header. Minimum flow rate for 25.4mm pipe is 4.5 L/min.
Max. Primary Loop Temperature:	
Low Temp. Water Design:	95°C
High Temp. Water Design:	115°C
Maximum Operating Pressure:	Design pressure of primary loop
Approximate Fluid Temp. Rise (summer-noon-sunny day-nominal flow):	20°C
Fluid:	Wide variety of fluids including glycol & water

Sol-Pro evacuated tube collectors applied in a closed loop system must have continuous primary pump operation during hours of sunshine. The pump cannot be stopped through the action of a high temperature liquid sensor-controller. Stagnation of collectors must be avoided because of the potentially serious consequences such as:

- Steam formation in collector header
- Loss of anti-freeze through relief valve
- Air and oxygen entrainment
- Lack of circulation
- Premature breakdown of anti-freeze
- Frost damage
- Corrosion of system components

(B) SOL PRO E-100 EVACUATED TUBE SYSTEM - cont'd

4. Operating Parameters (Medium-to-Large Capacity Systems) (cont'd)

Sol-Pro evacuated tube collectors applied in drain-back systems using water as the primary circuit fluid can become subject to stagnation without affecting the collectors or the system, however a high limit temperature sensor, located at the collector header, must prevent pump operation at temperatures above 110°C in order to prevent steam flashing, water hammer, and thermal shock of collector header.

5. Instrumentation Guidelines

The following notes apply mainly to medium-to-large capacity systems where automatic control and monitoring is essential. For smaller packaged DWH systems, reference can be made to the Phase I Manual - "Closed Loop Systems" for details on the simpler operational monitoring instrumentation for such installations.

1. Temperature Indicators:

Temperature indicators are necessary for routine checks and to afford detection of abnormal operating conditions.

Experience has shown that commercially available bimetallic or liquid-filled thermometers are of little use to the solar system operator. Such thermometers are usually out of calibration to a point where a comparison of fluid temperatures becomes meaningless.

5. Instrumentation Guidelines - cont'd

1. Temperature Indicators - cont'd

Both the primary and secondary circuits have wide ranges in operating temperatures, eg: 5°C to 95°C. The relative temperatures, or temperature differentials, between circuit supplies and returns and the approach temperatures between primary and secondary circuits, however, are small in evacuated tube closed loop solar heating systems:

- During maximum insolation, the temperature difference between collector feed and return is usually 4°C to 20°C.
- The average difference on a sunny day between collector feed and return is 2°C to 10°C.
- The temperature differential between secondary circuit supply and return fluctuates between 0°C and 10°C.

and

- The approach temperature between primary circuit (collector loop) return and secondary circuit supply (leaving heat exchanger) usually fluctuates between 0°C and 20°C.

In addition to knowing the temperature levels of the primary/secondary circuits, it is the knowledge of the foregoing temperature differentials which indicates to the operator whether or not the solar heating system is operating correctly. Because the temperature differentials within the primary and secondary loops are small (0-20°C) but may occur anywhere within the system operating range of 5-95°C, temperature sensors of exceptional accuracy and linearity are required to permit meaningful measurements.

5. Instrumentation Guidelines - cont'd

1. Temperature Indicators - cont'd

For a typical operating temperature differential of 8°C-10°C, two measurements of plus or minus 0.5°C accuracy will produce a reading within 1°C, or 10% of the actual value. For the purpose of performance monitoring, this accuracy is considered a minimum standard.

Principle Types of Temperature Sensors

Reference should be made to the Phase II Manual concerning Medium-to-Large Capacity Closed Loop Systems for a detailed discussion of liquid-filled, bimetallic, thermocouple, thermistor, integrated circuit and platinum RTD temperature sensors.

2. Sensor Installation

It is recommended that all temperature sensors be installed in stainless steel thermometer wells located at piping tees in the solar system circuits. This would allow service, replacement and calibration procedures to be accomplished without loss of system fluid. Sensors should be installed in the wells with silicone thermal conductive compound to ensure accurate readings. Smaller systems should use Peterson plugs to permit temporary access with electronic thermometers and pressure gauge probes.

(B) SOL PRO E-100 EVACUATED TUBE SYSTEM - cont'd

5. Instrumentation Guidelines - cont'd

3. Provisions Made for Collector Bank Water Balancing

Provisions should be made at each individual collector bank of large systems to allow measurement of the collector return temperature. During system commissioning, this will facilitate water balancing in an effort to achieve uniform flow through the collectors. The balancing would be performed on a sunny day with the system operating. On a sunny day with the system operating, each collector bank should indicate the same temperature differential between feed and return. During operation, periodic checks should be made to verify that equal flow exists.

A temperature imbalance would also point to possible evacuated tube failures or a collector bank air lock; a situation which can occur after a system has stagnated. It is recommended, therefore, that thermal wells or Peterson plugs be installed at the outlet of each collector bank, suitable for the insertion of a portable electronic probe.

4. High Temperature Alarm

Without fluid circulation during periods of insolation, the collector will stagnate. The fluid in the collector headers may reach temperatures above 100°C and the transformation of the anti-freeze fluid to a vapour becomes possible. Consequently, the system pressure may increase and some fluid may be discharged through the relief valve. A stagnated collector is also subject to increased thermal expansion and potential leaks.

5. Instrumentation Guidelines - cont'd

4. High Temperature Alarm - cont'd

On a system with automatic air vents, anti-freeze may be lost in the form of vapour. (Manual shut-off valves should normally be installed under each air vent). In large systems it is recommended that a temperature sensor be installed in the pipe as close as possible to the outlet of a designated collector to provide an alarm signal whenever temperatures in excess of 95°C are measured.

5. Pressure Gauges:

(a) Primary Circuit Pump - (Closed Loop)

A pressure gauge through switchover valves should be installed across the primary circuit pump, capable of measuring pump suction or discharge pressure as follows:

1. When the pump is off the gauge will read system static pressure.
2. During pump operation, (provided that the expansion tank is connected near the suction side of the pump), the gauge will read pump head plus system static pressure.
3. The difference between the two readings will be the pressure of the pump head.
4. The gauge can be used also to check whether flow exists in the primary loop by manually closing off any one valve installed in the primary loop while the pump is running. Once the valve is shut, the discharge pressure should rise slightly. The resulting pressure will indicate system static pressure plus pump "shut-off head". This test, however, should not be performed on a routine basis; rather it may be performed as a means of trouble-shooting. In order to avoid pump overheating, the valve in the circuit should not be left closed for any length of time.

The pressure gauge is also useful to initially charge and pressurize the primary circuit. The "fill pressure" or safe minimum operating pressure, is calculated by the system design Engineer and varies among installations. As the temperature of the fluid in the closed loop increases, the system pressure increases.

A relationship of consistency will exist between the closed loop fluid temperature and the system pressure. This relationship should be determined and recorded for comparison purposes during the commissioning of the installation. This relationship is more pronounced on large volume systems of higher buildings.

If this relationship changes, there has been a change in the quantity of fluid contained in the closed loop. Fluid may have been lost through:
- the pressure relief valve
- the air vent
- the pump seals
- a leak in the piping system
- a leak in the heat exchanger
- defective expansion tank (water logged).

(B) SOL PRO E-100 EVACUATED TUBE SYSTEM - cont'd

5. Instrumentation Guidelines - cont'd

5. Pressure Gauges - cont'd

(a) Primary Circuit Pump - (Closed Loop) - cont'd

If an unusually low pressure exists, (below established fill pressure), the system may not be pressurized relative to atmosphere at the top of the loop; a vacuum may exist and air entrainment is possible. In this case, fluid must be added and the system purged free of air.

If an unusually high pressure exists and the relief valve has discharged fluid, the reasons could be:

- fill pressure originally set too high
- pump not operating - collectors overheating with possible steam build-up; stagnation conditions.
- no flow condition in closed loop
- expansion tank defective - water logged
- expansion tank too small for system
- system temperature unusually high, over-collection of solar heat - possible steam formation in collectors

(b) Heat Exchanger:

The provision of pressure gauges to measure the primary circuit fluid pressure drop across the heat exchanger on large systems is considered optional. If no gauges are provided, ports or Peterson plugs should be installed.

(B) SOL PRO E-100 EVACUATED TUBE SYSTEM - cont'd

5. Instrumentation Guidelines - cont'd

5. Pressure Gauges - cont'd

(b) Heat Exchanger - cont'd

Pressure gauges may be used to detect a change in differential pressure due to heat exchanger fouling or blockage. An increased pressure drop through the heat exchanger, however, would automatically reduce the flow through the primary loop and this, alternatively, could be detected by an increase in the operating temperature differential between collector feed and return lines.

(c) Secondary Circuit Pump

A pressure gauge with switch-over valves should be installed to facilitate indication of suction and/or discharge pressure.

6. High-Low Pressure Alarm

In order for the closed loop (primary circuit) to operate correctly, the system pressure must stay within prescribed limits.

On large systems it is recommended that a pressure sensor with high and low contacts be provided and wired to the status panel for alarm annunciation.

(B) SOL PRO E-100 EVACUATED TUBE SYSTEM - cont'd

5. Instrumentation Guidelines - cont'd

7. Elapsed Time Indicator - Primary Circuit Pump

The provision of an elapsed time meter showing accumulated run time of the primary circuit pump will give the operator reasonable indication of the solar system performance. Control system problems, and especially abnormal continuous operation with resulting energy waste, may be detected by regular observation of run time.

On packaged systems controlled by preset time clocks this indicator would not be useful other than for verifying the operation of the control timer, and may be omitted.

8. Event Counter

The event counter is an electro-mechanical device indicating number of primary loop pump on-off cycles. This relatively inexpensive device would be very useful to set up initially the temperature differential settings activating and deactivating the circulating pumps. In addition, the event counter could be useful in detecting abnormal and erratic cycling due to intermittent wiring connections.

For systems controlled by time clocks, only one cycle per day would normally be counted.

9. Freeze Protection

Regular monitoring of the physical and chemical properties of the heat transfer liquid is essential to guarantee frost protection of the primary circuit. Reference should be made to the "Packaged Closed Loop Systems" manual for information concerning the monitoring and maintenance of the anti-freeze solutions.

(B) SOL PRO E-100 EVACUATED TUBE SYSTEM - cont'd

5. Instrumentation Guidelines - cont'd

9. Freeze Protection - cont'd

Automatic frost protection must be considered for the secondary circuit because of the possibility of freeze-up under certain abnormal conditions:

(a) The secondary side of the heat exchanger can become subject to freeze-up if the primary circuit pump runs out of control.

(b) It is possible to freeze the secondary circuit upon start up and subsequent cycling of the primary pump where a large amount of antifreeze exists in pipes exposed on the roof.

If water always circulates through the secondary circuit when the primary circuit pump is in operation, however, the probability of freeze-up is reduced greatly.

Recommended Frost Protection Procedures

1. Primary circuit pump permitted to operate only if flow is proven in the secondary circuit.
2. Freeze protection thermostat set at 5°C, installed in collector return line near heat exchanger, to shut down primary circuit pump.
3. Time delay relay set between 1 and 5 minutes to delay pump shut-down and alarm to prevent nuisance tripping upon start-up. Systems with large quantity of anti-freeze exposed to the outdoors (pipes on roof), will require longer time delay than systems with a limited amount of exposed piping.
4. A visual and audible alarm should annunciate the shut-down under "Freeze Conditions".

6. Operational Monitoring and Maintenance Procedures

The type and extent of instrumentation provided for operational monitoring is considered to be that necessary to furnish the operator with sufficient information to make routine diagnoses, to calibrate and adjust the controls, and to ensure annunciation of alarm conditions.

The "Operator's Check List" should be used to record operating conditions and to perform operational analyses. Certain modifications and amendments may be required to the check list in order to suit the actual system design concept. The frequency of use depends upon the complexity and performance record of the solar system.

The "Maintenance Schedule" separates the system into components and lists the recommended procedures and frequency of each maintenance task. This schedule may have to be expanded or altered in order to accommodate other design concepts or specific manufacturer's recommendations.

The Operational Problems Chart serves as an aid to system trouble-shooting.

The use of the "Operator's Check List" may help in the detection of operational problems. The "Operator's Guidelines" reflects system concepts illustrated in this manual and explains the operation of individual control and monitoring components. It will help the operator to properly control and monitor the system, to identify problems, and to perform the necessary corrective measures.

OPERATOR'S CHECK LIST

EVACUATED TUBE CLOSED LOOP SOLAR WATER HEATING SYSTEM

PROJECT:

SYSTEM MANUFACTURER:

OPERATOR:

MONTH:

YEAR:

Date and Time	Weather (Check One)			Approx. Outdoor Temp. °C	Power On Yes or No	Pumps On		Temperatures (°C)								System Press. kPa	Elapsed Time Hours & Tenths of Hours	Interval Counter Total Counts	System Alarms				Overflow Containers (Wet/Dry)		Visible Leaks Yes or No
								Heat Exchangers				Storage Tanks		Water Supply					Coll. High Temp Yes or No	Low Limit Yes or NO	Pressure				
								Primary		Secondary											High Yes or No	Low Yes or No			
	SUNNY	PARTLY SUNNY	CLOUDY NO SUN			Primary	Secondary	IN T-1	OUT T-2	IN T-3	OUT T-4	Solar T-5	Aux. T-6	Hot T-7	Cold T-8								Closed Loop	Solar Storage Tank	

MAINTENANCE SCHEDULE - SOL-PRO EVACUATED TUBE SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
Complete System	Operational Checklist	x	x	x	x	x	Initially more frequently, then as required.
COLLECTORS:							
Tubes	Inspect for leaks, breakage, overheating tubes. Tubes should feel cool on sunny days. Replace if hot		x				Barium getter within tube may turn white if vacuum is lost
	Manage snow		x				Winter months only
	Wash externally with warm soapy water					x	Including reflector, more often if dirty
Supports/Mounting and Fasteners	Check structure, tighten bolts, inspect isolation pads, touch-up where corrosion is evident					x	
Piping	Inspect hangers and supports. Adjust, check pipe slopes					x	Resupport pipes if sagging
	Check flow balancing for each collector array (large systems). Complete balancing procedures are outlined in Solar Programs Office Commissioning and Monitoring Procedures Documents					x	Temperature at inlet/outlet of each array can be measured with calibrated electric thermometer near noon on a sunny day (with system running)
	Verify pipe jackets and insulation. Repair weatherproof jackets where necessary. Replace wet fibreglass insulation. Inspect for UV degradation of plastic pipe jackets.					x	
	Check pipe conections and roof penetrations					x	Use 95-5 solder for copper pipe repairs

MAINTENANCE SCHEDULE - SOL-PRO EVACUATED TUBE SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
COLLECTORS: (cont'd)							
Control Modules	Verify wiring/connections and mounting of sensors					x	On small systems use timers instead of temp. sensors
EXPANSION TANK							
Diaphragm Type	Drain system. Check precharging. Replace with EPDM type if waterlogged					x	Usually 85 kPa, or as specified
Tank Type	Check level. Recharge if required			x			Also upon alarm signals. Tanks are normally sized to be 1/3 full when fluid is cool, 2/3 full when system is at maximum temperature
Open Type	Check fluid level. Fill if necessary. If automatic, inspect and clean probes			x			
PUMPS AND MOTOR CONTROLS							
Motors	Check amps, temperature, RPM					x	
Contactors and Switches	Inspect and torque connections. Check for pitting; replace points					x	
Bearings	Listen for vibration/noise. Lubricate				x		Where applicable
Seals	Check carbon/ceramic, O-ring and mechanical seals for vibration, noise or leakage			x			As per manufacturer's recommendations. Replace if leaking

MAINTENANCE SCHEDULE - SOL-PRO EVACUATED TUBE SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
PUMPS AND MOTOR CONTROLS (cont'd)							
Couplings	Inspect for play. Tighten if loose			x			
Mounting and Alignment	Verify. Adjust if required					x	
Impellers	Listen for noise. Measure developed pressure				x		
HEAT EXCHANGER	Measure & record pressure drop through convertor			x			
	Clean and inspect units as per manufacturer's recommendations. Service if pressure drop exceeds initial value by 20%.					x	Shell & Tube Exchangers: If floating heads, rod-through tubes. If bundle type use chemical cleaning & flushing. If plate type, disassemble and clean using fibre brush with soda ash/detergent solutions.
	Replace gaskets						As necessary.
STORAGE TANKS	Inspect tank insulation					x	
	Inspect linings for cracking, deformation or melting. Storage tank lining to be identified & labelled.					x	Repairs should be performed as per manufacturer's recommendations. Different tanks have significantly different maximum temperature limitations and repair & maintenance requirements.

MAINTENANCE SCHEDULE - SOL-PRO EVACUATED TUBE SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
STORAGE TANKS (cont'd)							
	Typical linings for tanks include directly applied cement (sometimes referred to as 'stone-lined'), cement applied to welded mesh, calcium aluminate coatings (eg: "Alcrete"), skin-tight copper linings, epoxy finishes and vinyl plastic sheet inserts.						All can benefit from frequent flushing and cleaning.
	Verify condition of magnesium anodes and other corrosion protection devices.					x	Where installed.
Cement Lined	Drain, open manhole, carefully inspect lining. Patch with material/method recommended by manufacturer. Remove debris, flush, replace gasket if necessary and refill.					x	During winter months, preferably on cloudy day. Provide adequate lighting and ventilation.
Glass Lined	Inspect. Repair/replace as per manufacturer's recommendations					x	Required only if blocked or if corrosion evident in water supply can be traced to tank.
Plastic (Vinyl or Epoxy)	Inspect for damage, leaks or discolouration. Drain, remove debris then flush. Repair as per manufacturer's recommendations.					x	Water should not penetrate behind these liners.
Probes & Sensors	Disconnect, clean and manually test if possible					x	Well-mounted units can be accessed externally.

MAINTENANCE SCHEDULE - SOL-PRO EVACUATED TUBE SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
PIPING ACCESSORIES							
Primary and Secondary Loops	Verify mounting, hangers and slopes. Check for leaks and damaged or wet insulation					x	Repair as required
Valves	Manually operate. Check for stem leaks etc. Inspect glands and seals. Verify that they are returned to balanced or normal (NO/NC) operating positions					x	Replace if necessary. Valves should have tags attached, stating their function & normal setting
Check Valves/ Vacuum Breakers	Open, clean and verify operation where possible. Check springs on spring-operated valves.					x	
Strainers	Open, remove basket, clean and flush			x		x	More frequently if indicated by excessive pressure drop, and during start-up
Water Filters	Monitor pressure drop.			x			Replace media/cartridge as required.
Relief Valves	Inspect if outlet port & discharge pipe are clear. Manually operate levered type. Verify setting if adjustable.					x	Replace overflow container under outlet pipe (if present).
Air Vents	Ensure floats and seals are clean on serviceable units. Check that vent caps are loosely screwed on. Inspect for leaks.				x		Should be isolated by shut-off valves after commissioning.

MAINTENANCE SCHEDULE - SOL-PRO EVACUATED TUBE SYSTEMS

COMPONENT	PROCEDURE	DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	COMMENTS
PIPING ACCESSORIES (cont'd)							
Fluids	Check pressure. If necessary top up with specified solar anti-freeze solution				x		Chronic loss of liquid indicates system fault; check for leaks in pipes, valves and air vents.
	Inspect for presence of colour or suspended solids.			x			
	Measure anti-freeze strength, pH and alkalinity. Conduct additional chemical tests and treatment as formulated for the particular solar system fluid.						Important before winter season. See Operator's Guidelines. Also check after hi-temp alarms or if collector stagnation is suspected.
CONTROLS AND MONITORING INSTRUMENTATION							
Differential Controller	Verify correct system status indications for "OFF", "MANUAL" & "AUTOMATIC" control positions. Check that pumps are actually running per control indications.			x			
	Turn power off, then reset to verify controller start-up operation.			x			Preferably on sunny day.
	Measure and adjust controller "ON" and "OFF" temperature differentials					x	Some controllers give direct electronic or digital readouts; others require the placement of sensors in temperature baths to fully verify setpoints

MAINTENANCE SCHEDULE - SOL-PRO EVACUATED TUBE SYSTEMS

COMPONENT	PROCEDURE	SCHEDULE					COMMENTS
		DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	ANNUALLY	
CONTROLS AND MONITORING INSTRUMENTATION (cont'd)							
System Status Panel	Operate and reset all alarm and status-indication circuits (high water, low water, high temperature, low temperature etc.)				x		
	Check elapsed time meter & event counter for proper operation.			x			
Temperature Readout Panel	Record temperatures at all sensing points and verify (T-collector out T-collector in etc.)		x				Pumps must be circulating for several minutes before readings are taken.
	Withdraw sensors from wells and check as-installed calibration at ice-point & boiling point of water					x	Required at least once during lifetime of a system & more often if system uses sensors other than platinum RTD units.
Wiring (Power)	Check insulation near controllers, contactors & motors for signs of shrinking or brittleness. Inspect for physical damage of wire or conduit					x	Overheating of wire may be due to poor relay contacts, loose terminals or overloaded pump motor; check.
Wiring (Sensors)	Verify that junctions, protective conduits and shielding are intact. Loosen off and retighten terminal screws.					x	

OPERATIONAL PROBLEMS CHART

On smaller, "packaged" domestic hot water systems, not all of the specified automatic monitoring instrumentation will be installed.

For these systems use must be made of the simpler, manually inspected devices (eg: flow indicator or elapsed time meter) in order to verify correct system operation.

OPERATIONAL PROBLEMS

SOURCE OF PROBLEM	POSSIBLE CAUSES	CONSEQUENCES	PERFORMANCE MONITORING
PUMP: Failure to operate when required to.	- Power off, Blown Fuse or Tripped Breaker - Not started through controller - Motor burned out - Impeller seized, blocked or disconnected. - Electrical Problem - Open circuit in collector sensor wiring.* - Short circuit in storage tank sensor wiring.* - Control System Problems	- No collection of solar heat - Overheating of the transfer fluid - Steam build-up and loss of fluid - Stagnation Conditions: -Accelerated breakdown of antifreeze. -Corrosion -Frost damage	Flow Switch and Alarm Collector High Temperature Alarm Observation of Elapsed Time Indicator Observation of Event Counter Observation of Temperatures
PUMP: Operating when not required to:	- Control set to Manual Op. - Problem with sensors and/or controller - Faulty Switch - Faulty Wiring - Closed circuit in collector sensor wiring.* - Open circuit in storage tank sensor wiring.* - Control System Problems	- Reverse heat exchange - Freeze-up of storage tank.	Low Temperature Alarm Frost Protection Thermostat to shut down pump Observation of Elapsed Time Indicator Observation of Event Counter Observation of Temperatures Observation of Flow Indicator
EXPANSION TANK:	- Water-logged, diaphragm burst. - Insufficient size - Originally charged too high -(Fill pressure too high) - Originally charged too low	- Build-up of pressure - Transfer fluid relieved - Air entrainment - Loss of circulation - Pump overheat - motor seized - Stagnation Conditions: - Breakdown of anti-freeze. - Corrosion - Frost damage	High Pressure Alarm Low Pressure Alarm Collector High Temperature Alarm Observation of Pressure Gauge Observation of Overflow Container

* Small systems may use electric timer to control daily operation

OPERATIONAL PROBLEMS
(cont'd)

SOURCE OF PROBLEM	POSSIBLE CAUSES	CONSEQUENCES	PERFORMANCE MONITORING

CONTROLLER:
Not operating correctly
	- Not adjusted correctly
	- Sensors loose*
	- Faulty wiring
	- Faulty electronics
	- Faulty switches
		- Inefficiency
		- Stagnation Conditions:
		  - Breakdown of anti-freeze.
		  - Corrosion
		- Frost Damage
			High Collector Temperature Alarm
			Low Temperature Alarm
			Observation of Elapsed Time Indicator
			Observation of Event Counter
			Observation of Temperatures
			Thermometers
			Max. Collector Temperature Indicator

AIR VENT:	- Shut-off valves at automatic vents left open. - System originally charged too low	- Lack of circulation - Lack of heat collection - Pump overheating - Stagnation and Resultant Damage	High Collector Temperature Alarm Low Pressure Alarm Observation of temperatures Periodic verification of temperature rise through collector banks Observation of pressure gauges. Observation of Flow Indicator
NO CIRCULATION Pump Running	- System air locked - Leak in piping system (fluid lost) - Part of piping system frozen up - Blockage in piping system - Impeller or drive defective	- No collection of solar heat - Stagnation and subsequent consequences (see above) - Pump overheating	High Collector Alarm Low Pressure Alarm Observation of Temperatures Observation of Pressure Gauges Observation of Flow Indicator
LEAK IN PIPING SYSTEM	- Incorrect solder joints - Expansion/contraction causing break - Frost Damage - Corrosion	- Loss of system pressure - No collection of solar heat - Poor or no water circulation - Stagnation Conditions & subsequent consequences - Pump Overheating	Low Pressure Alarm High Temperature Alarm Observation of Pressure Gauges Observation of Temperatures Visual Inspection Observation of Flow Indicator
FROST DAMAGE TO PRIMARY CIRCUIT	- Transfer fluid lost its freeze protection ability	- No flow - Break in piping circuit - Loss of fluid	Regular check of quality of anti-freeze

* Small systems may use electric timer to control daily operation

OPERATIONAL PROBLEMS
(cont'd)

SOURCE OF PROBLEM	POSSIBLE CAUSES	CONSEQUENCES	PERFORMANCE MONITORING
FROST DAMAGE TO SECONDARY CIRCUIT	- System operation out of control - Sensor(s) have come loose - Controller or sensor defective - Pump secondary circuit not running - Electrical fault	- Reverse heat exchange - Frost damage to secondary system tank and pipes - Flooding	Low Temperature Alarm Pumps interlocked such that primary pump can start only when secondary circuit pump is operating (flow switch for two pump systems) Automatic Pump Cut-off ('freeze stat)
RELIEF VALVE Keeps popping	- Fill pressure too high - Defective relief valve - Expansion tank water-logged - Expansion tank too small for system	- Loss of fluid - Air entrainment - Lack of fluid circulation - Stagnation Conditions and subsequent consequences	High Pressure Alarm Observation of anti-freeze discharged to overflow receiver Observation of Pressure Gauge
CROSS CONTAMINATION (for systems with direct heat exchanger)	- Leak in heat exchanger	- Loss of system pressure - Increase of System pressure	Pressure Gauge High Pressure Alarm * Low Pressure Alarm * Checking quality of anti-freeze Pressure testing primary circuit at least twice each year
CHECK VALVE			
Stuck Open	Dirt/foreign matter in system	- Reverse flow due to gravity circulation	Observation of flow. Check pipe loop temperature
Stuck Closed	Dirt/foreign matter in system	- Reduced or no flow, stagnation and subsequent consequences.	Observation of flow, pump pressure, temperatures.

* Part solution only

OPERATOR'S GUIDELINES

CLOSED LOOP EVACUATED TUBE COLLECTOR SYSTEMS

1. SUNNY CONDITIONS AND PARTLY SUNNY CONDITIONS

The solar system should be cycling.

2. CLOUDY OR NO SUN CONDITIONS

The solar system may cycle only if the ambient outdoor temperature is sufficiently higher than the incoming water temperature or the temperature existing at the bottom of the solar storage tank.

3. POWER

If solar system does not perform as described under the above weather conditions, check main and branch circuit breakers.

4. PUMPS

1. Secondary Circuit Pump

Secondary circuit pump is activated and de-activated through differential temperature controller and should cycle as described under paragraphs 1 and 3. If NOT, check:

- power conection, starter relay and wiring
- Differential controller setting
- Control sensor connections and transmission
- Controller

Note: If freeze thermostat has shut down the primary circuit pump, the secondary circuit pump should remain in operation as long as contact is made through the differential controller.

4. PUMPS - cont'd

2. Primary Circuit Pump

Except where stopped through the freeze 'stat, this pump should always run when the secondary circuit pump is operating.

If this is not the case, check:

- that all valves are open in secondary circuit
- flow switch and control wiring
- Primary circuit pump starter, relay power wiring & motor.
- Secondary circuit flow through pressure gauge as described under paragraph 5.5.(a).4. (page 54). If no flow, check pump motor, coupler and impeller.
- Physical blockage in heat exchanger or pipes.

5. ELAPSED TIME METER

On a sunny day, the system should always have some run time. The number of hours that the system (pump) runs depends on:

(a) How much domestic hot water is drawn
(b) Hours of sunshine
(c) Time of year
(d) Outside temperature

The system may also run (cycle) on cloudy days or at night provided that the domestic water temperature entering the solar tank is much colder than the outdoor ambient temperature. Such run time, however, should be minimal. If the elapsed time meter shows excessive running (eg: more than 10 hours on a sunny day), a control problem may exist. Check if temperature sensors have come loose at collector or at storage tank.

5. ELAPSEL TIME METER - cont'd

If elapsed time meter shows no operation during sunny periods, check whether:

(a) Temperature sensors have come loose or detached at collector or storage tank.

(b) Freeze temperature setting is incorrect.

(c) System is off on "freeze".

6. EVENT COUNTER

This instrument is useful to detect excessive cycling of primary circuit pump or the absence of cycling.

Excessive cycling may indicate:

- Control system temperature differential settings too close.
- Control system problems
- Intermittent wiring connections

Absence of, or very infrequent cycling may indicate:

- Control system temperature differential settings too wide.
- Control system problems
- Open or shorted temperature sensors.

OPERATOR'S GUIDELINES

7. CIRCUIT TEMPERATURES

Refer to "Closed Loop" diagram on Page 47.

- T-1 temperature should always be higher than T-2.
- The temperature differential should not exceed 18-20°C at maximum insolation. If higher temperature differentials exist, and the loop operates at a reduced flow rate, check for:

  - partially closed valves
  - dirty strainer
  - pressure limits
  - blockage
  - air lock
  - pump problems

- During sunshine periods with pump operating, a small temperature differential should always exist. If this is not the case, check:

  - valves closed in collector loop
  - No-flow for any reason
  - snow covered collectors
  - system air locked
  - system operating outside of pressure limits
  - pump/impeller disengaged
  - freeze-up of collector loop

T-1 and T-2 temperature levels will fluctuate between 5°C and 95°C. Elevated temperature levels indicate large reserves of solar heated water. Without domestic water consumption, overcollection will result. This would lead to excessive loop temperature and pressure, and subsequent discharge of fluid through primary and/or secondary circuit relief valves.

7. CIRCUIT TEMPERATURES - cont'd

It is recommended that the system be set up such that the secondary circuit pressure/temperature relief valve pops before the primary circuit relief valve. This will safeguard against the loss of valuable anti-freeze.

While the secondary pump operates, T-4 temperature should always be higher than T-3 temperature. If this is not the case, there may be no-flow through the secondary circuit, the primary pump may be shut down on "Freeze" condition, or a control system problem may exist leading to reverse heat exchange.

T-4 temperature should always read lower than T-1 whenever the pumps are operating.

Temperatures 1, 2, 3, 8 and possibly 5, may read near room temperature during periods when no flow exists through these circuits.

T-5 will read the temperature of the stored water. This temperature usually varies between 5°C (high domestic water draw without solar energy collection) and approximately 80°C (little or no domestic water drawn in combination with maximum solar energy collection).

T-6 will read the temperature of the domestic water in the auxiliary heating tank; normally set between 50°C and 80°C.

T-7 is the domestic hot water supply temperature, normally maintained between 45°C and 70°C.

T-8 reads incoming cold water temperature.

OPERATOR'S GUIDELINES

8. CALIBRATION OF SENSORS

Calibration of all temperature sensors in their "as-installed" configuration can permit a system operator to monitor and maintain a solar domestic hot water circuit with significantly increased efficiency, accuracy and confidence. A simple calibration procedure using readily available materials may be performed at the ice-point of water (0.0°C) and at the boiling point of water (100°C), depending upon the atmospheric pressure:

> Crushed or broken ice is placed in a wide-mouth thermos containing cold water and the mixture is allowed to equilibrate. As long as significant quantities of both ice and water are present, the temperature of this mixture rapidly reaches 0.0°C (plus or minus 0.1°C) and is little affected by the local temperature or atmospheric pressure. One by one the temperature monitoring probes are withdrawn from their wells and placed in the thermos (near their original place of installation) and, after a settling period, the temperature is read at the central indicator unit.
>
> If 'zero' adjustment is possible, then each sensor channel is set to read 0.0°C while its corresponding probe is in the ice water bath; otherwise, a note of the observed error at 0°C (eg: T1 is 0.3° high, T2 is 0.5° low, etc) is made and clearly posted.

The same basic method is employed for the 100°C point except that water boiling vigorously on a hot plate is used and correction should be made for the atmospheric pressure.

8. CALIBRATION OF SENSORS - cont'd

The 'standard atmospheric' pressure is 101.3 kPa; the boiling point of water decreases approximately 0.3°C for each kPa reduction in pressure and increases 0.3°C for each kPa increase in pressure. At a local pressure of 100 KPa, therefore, water can be expected to boil around 99.6°C. The actual boiling point is thus determined and the sensor instrument error is adjusted or recorded as required.

9. SYSTEM PRESSURES

The pressure in the primary loop will fluctuate between the specified minimum fill pressure (system cold) and maximum operating pressure (system hot). Problems will result if the pressure is too low or too high:

> Too low a pressure will cause a vacuum at the elevated portions of the loop, resulting in possible air entrainment etc.
>
> Too high a pressure will result in overflow.

The hi-low pressure alarm will annunciate abnormal operating pressures.

Upon high pressure alarm:

- check whether alarm set point is correct
- check for collector stagnation or pump failure
- check for leak from domestic water circuit into closed loop through heat exchanger

9. SYSTEM PRESSURES - cont'd

Abnormally high pressure conditions may also result from expansion tank/system precharging problems, eg : air charge too high, collapsed diaphragm in original installation, or system originally charged too high (cold start).

Upon low pressure alarm:

- check whether alarm set point is correct
- check overflow container for loss of anti-freeze
- check for leaks in piping, collectors or heat exchanger
- check for expansion tank failure

The pressure gauge on the secondary pump will fluctuate with the city water pressure and is used to measure pump performance.

10. FREEZE PROTECTION THERMOSTAT

This instrument should be set at 5°C; it protects the secondary side of the heat exchanger from frost damage and stops the primary circuit pump through a time delay relay. The time delay relay is adjusted to prevent unnecessary cycling during start-up in very cold weather. During freeze alarm conditions, the secondary pump keeps running as long as the controller indicates useful solar collection.

The time delay may require adjustment to a longer period to account for cold fluid slugs which may occur in exposed parts of the primary loop.

11. COLLECTOR HIGH TEMPERATURE LIMIT THERMOSTAT

The collector high limit thermostat should be set to sound an alarm at temperatures in excess of 95°C; causes for which could be:

- Blown or tripped circuit breaker of pumps
- No-flow through collectors
- System air-locked
- System not pressurized at top of collectors
- Pumps not running
- Dirty strainer - blockage in piping system
- Control system problems

12. HEAT TRANSFER LIQUID

The primary circuit is usually charged with a propylene glycol/water solution with a corrosion inhibitor added.

The lower the temperature of the fluid in the loop and the lower the presence of oxygen, the better will be its physical and chemical stability. With elevated temperatures in the presence of free or dissolved oxygen, the oxidation process of the glycol solution is accelerated. This diminishes the effectiveness of the corrosion/oxidization inhibitor and decreases the strength (freeze protection) of the anti-freeze.

The duration of the frost protection and corrosion protection qualities of the solution varies from system to system.

Regular monitoring of the physical and chemical properties of the heat transfer liquid is essential to guarantee frost and corrosion protection. (Refer to "Packaged Closed Loop System" Manual).

APPENDIX A

Recommended Instrumentation Specifications For Evacuated Tube Systems - Medium-to-Large Capacity Systems

.1 Temperature Read-Out

1. Digital Temperature Readout for Panel Mounting:

Range:	0°C to 100°C
Resolution:	0.1°C minimum
Accuracy:	0.1% of scale plus or minus one digit, (max. 0.2°C) at 20°C
Stability:	100 ppm/°C
Type:	Standard Platinum RTD (DIN 43760), 3 or 4 wire lead-resistance compensated
Sampling Time:	1 second maximum
	segment L.E.D. or illuminated L.C.D., mm digits minimum.
Other:	Readout to be protected from damage caused by: - open RTD sensor line - shorted RTD sensor line - RTD short to AC line
Suppliers:	Omega Engineering Model 199 RTD Meter 1 Omega Drive, Stamford, Connecticut,USA
	Doric Model 410A, 3½ Digit Indicator Intertechnology, 1 Scarsdale Rd., Don Mills, Ontario.
	Enercorp Model PDAW-48 RTD Indicator P.O. Box 20, Station U, Toronto, Ont.
	Thermo Electric Analogic/ELS RTD Indicators, 12 Rutherford, South Brampton, Ont.

APPENDIX A

Recommended Instrumentation Specifications For Evacuated Tube Systems - Medium-to-Large Capacity Systems

2. Rotary Selector Switch for Panel Mounting

Selector shall be a ten-position, low resistance, ($< 0.01\ \Omega$) double or triple pole, make-before-break switch with screw-terminals, suitable for RTD measurements.

Suppliers: Omega Engineering Model OSW3-10 Rotary
silver-contact RTD switch,
1 Omega Drive, Stamford, Connecticut,USA

Doric Model 409A, 10 Input, 3-pole
Pushbutton switch. Intertechnology,
1 Scarsdale Rd., Don Mills, Ont.

Enercorp 10-position, gold contact,
Rotary switch, P.O. Box 20, Station U,
Toronto, Ont.

3. Wiring

Wiring shall be 3 or 4 wire (depending upon sensor), unshielded PVC-jacketed cable with #22 AWG stranded, tinned conductors (Belden 8443 or equivalent). Wiring shall be routed, without junctions, from control panel to position near sensor installation, then by flexible conduit to connection box affixed to thermowell. Connection to RTD sensor wires shall be made using a screw terminal block. Exposed wiring shall be run in metal conduit.

Suppliers: Electro Sonic Inc.,
1100 Gordon Baker Rd., Willowdale, Ont.

Cesco Electronics Ltd.,
4050 Jean Talon W., Montreal, Que.

APPENDIX A

Recommended Instrumentation Specifications For Evacuated Tube Systems - Medium-to-Large Capacity Systems

4. Temperature Sensors:

Sensors shall be Platinum RTD (DIN 43760) type, wire-wound or thin-film elements mounted in a rigid, heat-conductive shell, maximum diameter 6.4mm.

Minimum Performance Specifications:

Plus or minus 0.3°C at 0°C
Plus or minus 0.6°C at 100C

Suppliers:

Omega Engineering Model PR-12,
Platinum-100 RTD
1 Omega Drive, Stamford, Connecticut USA

HyCal Model RTS-30, Platinum RTD
Intertechnology, 1 Scarsdale Rd.,
Don Mills, Ont.

Enercorp Model Precision Pt-100 RTD
P.O. Box 20, Station U, Toronto, Ont.

5. Sensor Mounting:

RTD sensors shall be installed in stainless steel wells, positioned at piping tees as noted in the system diagram. Silicone heat-conductive compound shall be used to ensure good thermal contact between the element and the system fluid. Metal junction boxes or heads shall be affixed to the thermal wells in order to protect the sensor unit wiring and terminal block junctions. These boxes shall be designed to allow access to the temperature sensors for service and replacement.

A packing nut and gland shall be used to affix the temperature sensor to the thermal well and to reduce the external ambient heat effect on the sensor.

APPENDIX A

Recommended Instrumentation Specifications For Evacuated Tube Systems - Medium-to-Large Capacity Systems

5. Sensor Mounting - cont'd

For thermowells installed in cold water lines (T-3, T-4, T-5 and T-8 in system diagram), a waterproof sealant must be applied around the point at which the sensor wires pass through the packing nut in order to prevent condensation in the well and subsequent failure of the element.

6. System Status Panel

Provide a system status panel as illustrated on the large system diagrams. Panel to be approximately 250mm high x 300mm wide, black or dark colour "Lamacoid" surface with engraved lettering 12mm high, complete with "green" running lights and "red" alarm lights and alarm reset. Provide cut-outs for recessed mounting of elapsed time counter and event counter.

7. Freeze Protection Thermostat

Equal to "Penn" series A19, single-pole, single-throw, 110V, to break on temperature fall, range adjustable from -15°C to 40°C with manual reset button. Unit complete with bulb well and packing nut assembly, 12.5mm NPT adaptor and 110mm long stem. Install in thermal well in collector return line and wire to stop primary circuit pump. Provide also wiring to status panel for alarm annunciation.

8. High Limit Thermostat - Drain Back Systems

Equal to "Penn" A19 ABC11 complete with well assembly, range 38°C to 116°C, set at 90°C complete with capillary sensing bulb and well installed in drain-back receiver. Wire through latching relay to shut down primary pump and to annunciate high temperature condition at status panel.

Recommended Instrumentation Specifications For Evacuated Tube Systems - Medium-to-Large Capacity Systems

9. High Limit Thermostat - Closed Loop Systems
   Equal to "Penn" A19 ANC complete with rainproof enclosure, range 38°C to 121°C, set at 95°C complete with capillary sensing bulb and well installed at collector outlet. Wire through latching relay to collector system status panel to annunciate high collector temperature conditions.

10. Low Water Level Alarm
    Equal to "Penn" F63AC-1 liquid level float switch, wired to close circuit when liquid level falls below the required minimum level. Wire to annunciate low level condition at status panel.

11. High Water Level Alarm - Drain Back Systems
    Equal to "Penn" F63AC-1 liquid level float switch, wired to close circuit when liquid level rises above the maximum permissible level. Wire to annunciate high level condition at status panel.

12. Hi-Lo Pressure Alarm - Closed Loop Systems
    Equal to "Winters" double contact gauge, 150mm dial, range 0-700 kPa, complete with relays. Alarm pointers adjustable throughout range, complete with pet cock. Wire to status panel to annunciate high and low pressure alarm conditions.

13. Flow Switch: Primary Circuit - Drain Back Systems
    Secondary Circuit - Closed Loop Systems
    Equal to "Penn" F61KB-11 to be installed in primary circuit, wired to sound alarm at "no-flow" condition while pump is operating. Wire, also, to initiate secondary pump operation (drain back systems) or primary pump operation (closed loop systems) when flow exists.

APPENDIX A

Recommended Instrumentation Specifications For Evacuated Tube Systems - Medium-to-Large Capacity Systems

14. Pump Starters

Provide wiring from pump starters to the status panel running lights.

15. Pressure Gauges

150mm diameter face, black finished steel case, complete with brass pet cock. Range to suit installation parameters, equivalent to "Trerice" or "Winters". Install complete with switchover valves to measure pump suction and discharge pressure of primary and secondary circuits.

16. Overflow Containers

Provide overflow containers, permanently installed, to receive liquid discharge from pressure/temperature relief valves of primary and secondary fluid circuits. Minimum capacity: 10 liters.

17. Elapsed Time Meter

Electro-mechanical, 110 volt, AC synchronous motor-driven counter with non-resettable, 6-digit hour and tenths of hour indication, CSA approved. Equal to Bach Simpson #1357 ETIF.

18. Event Counter

Electro-mechanical, 110V, non-resettable, minimum 6-digit readout, CSA approved. Equal to "Hecon" AO-040. Minimum height of digits: 5mm. CSA approved.

APPENDIX B

Solar System Fluids

.1 Closed Loop Systems:

All closed loop solar domestic hot water systems require the use of a non-freezing, non-corrosive liquid as the heat transfer medium; the most commonly used fluids are glycol/water antifreeze mixtures. The two different glycols employed (propylene glycol and ethylene glycol) have significantly different properties and care must be exercised in order not to confuse them or inadvertently combine them.

All solar systems using glycol solutions should be clearly labelled as to which antifreeze is required.

Propylene glycol is used in most systems because of its relatively low toxicity (see Solar Programs Office Technical Note #4) although it has a lower specific heat, is more viscous, and is substantially more costly than ethylene glycol.

Double-walled heat exchangers must always be used in conjunction with ethylene glycol fluids in order to avoid toxic cross contamination; the relevent Provincial Codes should be consulted regarding the application of single-walled exchangers with propylene glycol.

In all cases it is important that the glycol solutions incorporate anti-oxidation inhibitors, buffers and bright food-grade dye colouring. Individual manufacturers should be contacted regarding the appropriate levels of additives in the solar antifreeze mixtures; in a 50% glycol/50% water mixture, the pH should be typically 7.5 to 9, and the residual alkalinity about 6 to 10 .

APPENDIX B

.1 Closed Loop Systems - cont'd

Simple paper-tape testing kits are available from certain suppliers (eg: Dow test strips for DOWFROST antifreezes) for routine maintenance of the fluids. Over time, with continuous exposure to heat and oxygen, glycols tend to oxidize to form organic acids which not only reduce the antifreeze protection but may also contribute to serious corrosion of the plumbing system components. If this degradation is detected early enough, (before the solution becomes acidic; $ph < 7$), additional inhibitors and buffers may be added to rejuvenate the fluid.

Testing of the strength, pH and reserve alkalinity of the antifreezes should be performed at least twice a year (Spring and Fall) and more often if stagnation, loss of fluid or over-collection problems arise. The most satisfactory way to test the freeze protection strength of the glycol is by using a hand-held refractometer. Again, it is most important to be sure of which glycol is being tested and that a mixture of the two does not exist.

When using either ethylene glycol or propylene glycol in a closed loop solar system, it must be ensured that all materials such as seals, diaphragm expansion tanks etc. are compatible with the antifreeze solution. Current indications are that tanks with EPDM rubber diaphragms and components with EPDM or Nordel rubber seals are suitable for long-term usage with either glycol.

The acidity of the antifreeze/water mixture may be determined with limited-range pH paper or a portable electronic pH meter.

APPENDIX B

.2 Drain-Back Systems:

Heat-transfer fluids in drain-back solar water heating systems do not normally employ any antifreeze protection. This is because the collectors and external pipe circuits are emptied during conditions when heat is not being collected by the system (by a differential controller, a timer, or during seasonal shut-down).

If all of the pipe circuits are designed and installed in a way which will ensure good drain-back times (3 to 5 minutes) and a freeze protection thermostat is installed, then no major freeze-up problems should be encountered. In large, semi-pressurized drain-back systems, however, some designers specify 10-20% glycol mixtures as added protection against frost damage. For such systems, glycol strength, pH and alkalinity should be monitored and maintained as outlined in the previous section, and special attention should be paid to restricting fresh air access to the circulating loop.

Most drain-back solar DHW systems use water as the heat transfer medium. This may be ordinary tap water, softened water, deionized water, distilled water, or chemically treated water, depending upon the specifications for the particular system. Smaller, packaged DHW systems generally use tap water because a relatively small amount of 'captive' circulating fluid is used and all of the pipe circuits, heat exchangers and tanks are copper or plastic. Evaporative losses are kept to a minimum by small vent lines or tank-penetration grommets. Some manufacturers recommend the use of a thin, silicone-oil film on top of the drain-back tank fluid.

.2 Drain-Back Systems - cont'd

Certain restrictions as to water hardness may be imposed on solar DHW systems which pass the domestic water supply directly through the collectors in order to prevent serious calcium deposits (scaling) and loss of efficiency. The use of cation exchange resin-type water softeners may be required to remove the metal ions from the solution.

Deionized water may be produced either by reverse osmosis or a double cation-anion resin exchange process. The resulting water has a very low dissolved solids and mineral content making it suitable for critical applications such as evacuated-tube collector drain-back systems.

In large solar systems incorporating schedule 40 black steel piping in combination with other plumbing components, softened or deionized water is often used in conjunction with neutralizing or oxygen-scavenging additives such as nitrites, borates or hydrazine. These chemicals may be added when systems are initially charged, but some provision (such as for a bypass chemical pot-feeder) should be made to allow for fluid maintenance and retreatment. For such cases, the services and recommendations of a specialty chemical treatment company should be obtained in order to ensure an optimum life for the system components.

The pH of water-containing systems is generally maintained in a range of 7.5 to 8.5.

.2 Drain-Back Systems - cont'd

Distilled water, produced by boiling the liquid and condensing the vapour, is similar to deionized water in that it is essentially mineral-free and is thus quite aggressive towards metals unless chemical additives are employed. It is also generally more expensive than deionized water and is, therefore, not often used in solar systems.

During normal operation of drain-back systems, water loss should be restricted to the small quantity of vapour and mist that escapes through vent lines, tank seals etc. Automatic make-up water valves are not recommended because of safety and maintenance considerations; it is important that all make-up water be manually monitored in order to detect system leaks and to ensure that any large quantities of added water are chemically treated as required. Continuous filtration of the water in the drain-back tanks of large solar systems may be accomplished without restricting the head of the main pump by using a small circulating pump, mounted directly on a pipe leg feeding from the bottom and delivering to the middle of the reservoir.

Complete changes of the primary-loop water and flushing of the system should be undertaken when significant colour and/or particle accumulation is observed in the flow meter/level indicators. Chronic build-up of colour and/or corrosion products may indicate air infiltration problems or a lack of die-electric isolation between dissimilar system components.

APPENDIX C

REFERENCES

In the compilation of Solar System Operational Monitoring and Maintenance Manuals, many references have been consulted, including:

The Solar Programs Office Technical Notes Series, Particularly No's 6, 9, 14, 20 and 21.

The Canadian Solar Industries Association Product Data Sheets (for all systems).

"Solar Systems Maintenance"; F.S. Dubin and K. Raman, ASHRAE Journal, December 1983

"New England Electric's Solar Project"; R. O. Smith and J. Meeker, Solar Age, March 1978.

"Guidelines for the Preparation of Start-up, Commissioning and Monitoring Procedures: Engineered Liquid Loop Systems"; Solar Programs Office, January 1984.

Internal Reports of the National Research Council Solar Energy Program's Office Concerning the Testing, Evaluation and Maintenance Problems of Closed Loop and Drain-back Packaged Solar Hot Water Systems.

"Mountain Spring Evacuated Tube System", Technical Report for Presentation to the International Energy Commission Conference, Australia, 1983; B. Carscallen, N.R.C.

Numerous Solar Water Heating Systems In Operation across Canada; Supplemented by Information from and Discussions with various system manufacturers.

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